The Advancing Era of Digitalization in the Field of Forensic Odontology

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ABSTRACT-

Digitalization increases productivity and improves human efficiency, while lowering subjective inaccuracy. The technological breakthroughs have opened up new possibilities for resolving cases, based on various aspects of forensics. In forensic odontology perspective, technologies will particularly be beneficial in disaster victim identification, where a large number of bodies have been gravely mutilated, as it would allow the digital transfer of images without loss of information. Digital equipments are now expensive but with advance in technology the cost of these devices will decrease, allowing them to be used in a wider range of specialties. In clinical dentistry, there is rapid evolution is use of advanced equipment for purpose of efficient clinical treatment. However forensic dentistry being at an infant stage lacks the familiarity to the available resources. The aim of the paper is to provide a comprehensive review of the various digital tools in forensic dentistry which can be used to maintain the high standards of dental forensic evidence and increase the value of the evidence being presented during the legal proceedings.

Keywords: Forensic dentistry, forensic odontology, digitalization, forensic dental evidence

Introduction

Digitalization means improving or enhancing any process by aid of digital technology or digital data. It increases productivity, human efficiency and reduces manual error. In simple words it can be defined as a process from human driven to software driven approach. Digitalization has also taken over gradually in the field of forensic dentistry.

The various domains including maintenance of digital dental records/ charts, smile photograph analysis, facial reconstruction, personal identification, virtual autopsy, 3D scanning and printing prove its scope in the coming generation for this field. These technological breakthroughs have opened up new possibilities for resolving cases based on applied aspects of forensic dentistry. It has transformed the principles of collection and analysis unlike the traditional forensic investigations.

The prime role of forensic odontologist is in identification of deceased during mass disasters. For this purpose, a strong antemortem and post-mortem data is necessary, after analysis of which a positive identification can be made. In addition, criminal cases of sexual assault, important forensic evidences like bitemarks and lip prints can be useful in identification of the suspects and to aid in further investigation.

I. Digital Dental Charts

Digital Dental Chart comprises of the patient's digital radiographs, dental history, treatment plan which can be saved in the system and also shared via digital media later. The advantages of this technology as compared to conventional dental chartings are as follows:

a. Can be potentially shared across the globe.

b. Provides visualization of the oral cavity.

c. Store large amount of data for longer period of time.

d. Economic and cost effective.

Technology has developed to a great extent but this practice has not been implemented in our country to its full extent. Proper maintenance of records is of immense importance not only from clinical perspective but also of forensic significance.[1]

I. Rugoscopy

The palatal rugae develop in the 3rd month of intra-uterine life. The patterns of palatal rugaeare different for every

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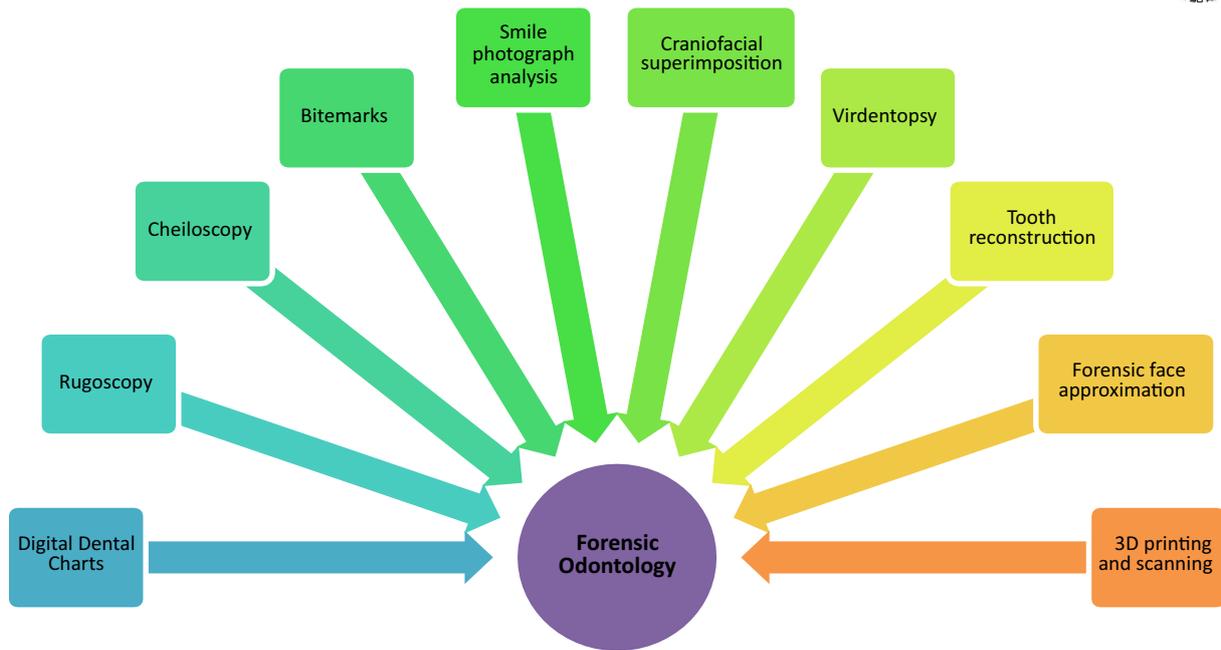
Figure 1 : Various domains of Forensic Odontology

individual. In twins too, they are not identical. Various factors contribute to the changes in the pattern such as habits of finger sucking during childhood, post extraction changes in the oral cavity, continuous force during orthodontic treatment. All these also bring about lateral edge pattern changes. Overlay after marking the rugae on the cast was the conventional way of determining palatal rugae match.These days, computer tools such as RUGFP-ID, Palatal Rugae Comparison Software (PRCS Version 2.0), and Adobe Photoshop can be used to superimpose digital pictures for comparing rugae patterns. Calcorugoscopy is a technique for comparing two or more rugae shape. The 3-dimensional imaging of the palatal rugae anatomy is obtained using stereoscopy. Stereophotogrammetry provides for the precise measurement of each palatal rugae's length and position. [2]

III   Cheiloscopy

Cheiloscopy, or the analysis of lip prints, is a time-consuming task when done manually, and the unique features cannot be evaluated with great precision. The Weighted Value Scoring System is a priority framework designed to help with feature analysis and scoring for each lip. The groove type was categorized based on Suzuki and Tsuchihashi in a study by Prabhu et al, and scores were assigned in whole numbers to different patterns, the grooves were color coded.[3] Using an indirect digital approach of scoring the lip print in Adobe Photoshop with color codes, all lines were recorded without missing any, and the error of recording the same groove twice was eliminated, which is the most common mistake

happening during manual documentation.

IV. Bitemarks

The computer produced overlay creation approach is currently used to compare the suspect's dentition with the bitemark utilizing digital tools. In comparison to other procedures that result in observer bias, it is thought to be extremely accurate and trustworthy. Dental casts are scanned on the scanner's glass plate for this. The photographs are then opened in Image J, GIMP, or Adobe Photoshop Software, and the 'Selection Tool' is used to make a progressive selection. The bite edge outlines are constructed, and an overlay is developed. [4]

The score is attributed as: Excellent matching – 3 Moderate matching – 2

Slight matching – 1 No matching – 0

Digital bitemark comparative analysis can be done in the following manner:

a.   Take series of photographs and formulate a 3D model.

b.   With an accuracy of 0.1mm, define the exact location of every given point in digital space.

c.   In digital space, create a visual volume model of the objects.

d.   Overlay the photogrammetric 3D model with 2D image of bitemark to improve visual properties of representation.

e.   Superimpose photographs onto the contours of the 3D model.

f.   Compare and analyse.

V. Smile Photograph Analysis

The global use of internet is quite evident in the recent times, as people tend to socialize by posting their pictures on various social media platforms. The primary aim of every missing person app is to find an individual alive whereas the use of application for deceased is not considered. The App Selfie Forensic Id was created with a view of maintaining dental information and characteristic dental findings of the anterior teeth of the persons, those who have registered in the application. Each individual has distinctive oro-dental features such as rotation, transposition, proclination, reclination, diastema, supernumerary teeth, crowding, fluorosis, discoloration, piercings etc. which could be cross checked during dental autopsy of the deceased unidentified individuals. Smile photographs with teeth visibility give prime dental information particularly when antemortem dental data cannot be retrieved. Such applications can be of immense significance in disaster victim identification.[5]

Identification of individual through smile photographs is comparatively less tedious and less expensive. Photographs are the most common sources of availing dental data, be it antemortem (AM) or post-mortem (PM).

Smile photograph comparisons can be made from various methods such as

a.	Layering Superimposition Technique
b.	Smile Line Superimposition. Layering Super Imposition Technique

Here we superimpose the AM and PM images gradually by layering technique; increasing the transparency. However slight changes in magnification of either AM or PM photograph may lead to discrepancy. But the discrepancies in each method can be resolved by combined use of multiple techniques.

The advantage is that these methods are highly reliable, less expensive and consume less time. [6]

Smile Line Superimposition Method:

The smile line is traced on AM and PM photographs, marking the incisal outline from canine to canine of upper anterior teeth. The two outlines are layered with gradual transparency 0%, 25%, 75%, and 100% and if they coincide there are chances they belong to the same individual.[6] However, it is an indefinite method and not so accurate because smile lines change with age or with some dental treatments like orthodontics. It cannot be solely used for identification but analysis can be made from comparing maximum points that are similar on AM and PM photographs.

## VI	Craniofacial_Superimposition

Craniofacial superimposition is a forensic procedure that compares images or video footage of a missing individual to the skull that has been discovered. Superimposition emphasizes on the critical variables necessary for the accurate comparison of the antemortem photographs to that of the skull photographs, radiographs or for more definitely distinct features the CT/CBCT images of the deceased. Comparison is made on basis of specific craniometric and cephalometric landmarks present on skull and photographs or radiographs. It can be created using advanced image applications such as Adobe Photoshop, Image J, and GIMP to keep the original proportion and scale, sharpness, clarity, chroma, saturation, and light management. The antemortem data is superimposed with the skull image using two layers. All of the correlations are kept in a 1:1 ratio. A high degree of morphological congruence between the skull and facial scans makes personal identification relatively likely.[7] The MEPROCS Project had been conducted purely for enhancing the techniques in craniofacial superimposition to achieve highly accurate results.[8] Computer aided craniofacial superimposition is divided into the following stages [9]:

a.	Face enhancement and skull modelling
b.	Skull-face overlay
c.	Decision making

## VII	Virtual Dentopsy

The "Virtopsy" virtual autopsy combines scanning and radiography technology with modern computer power and resolution. It is an important tool for determining the manner and cause of death. Furthermore, it eliminates the need to physically dissect the deceased, allowing examiners and investigators to find vital clues faster and more effectively. The captured scans can be replayed, allowing investigators to enlist the help of additional experts if necessary.Virtual autopsy is an added advantage in the field of medicolegal casework. However, it is at an infant stage in forensic odontology but with constant efforts and increasing awareness of non-invasive and touch free technique, it shall be of importance in the near future.

It is a combination of a wide scope of applicationon like MRI, CT, PMCT and 3D scanning.[10]

Virtopsy is a multidisciplinary advancement that is an amalgamation of forensic medicine, radiology, pathology,
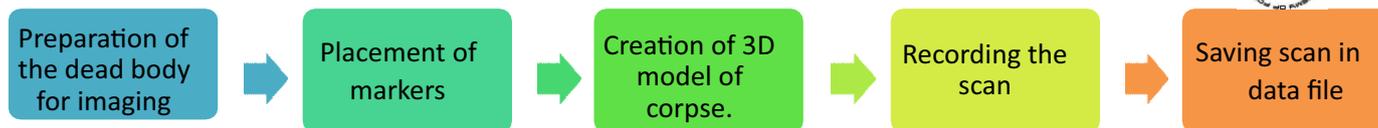
Figure 2 : Steps involved in Virtopsy

biomechanics and computer graphics.

The camera's resolution is 0.02 mm, and scanning takes no more than 10 seconds. The entire technique takes 20 seconds and generates 25000 pictures that can be sliced across the body. Pathologists have the advantage of practically peeling down layers of muscle and skin with a computer click. Radiology outperforms autopsy in cases of cranial, bone, and tissue injuries. Dental data is of essential relevance, according to Interpol's DVI rules, and virtopsy makes obtaining the postmortem record very quick and reliable. Exhumation is not necessary because the data has been saved. [11]

VIII. Tooth Reconstruction

The process of reconstructing the morphology of missing teeth from intra alveolar morphology of dental sockets in skeletal remains is known as forensic tooth reconstruction. In a study performed by Johnson et al, the CBCT machine was used to scan the skeletal remains. Later the data was saved and a 3D print was obtained .Heavy body addition silicone was used for obtaining a negative impression of the alveolar socket which would form the root in the 3D printed model. The crown portion of tooth is reconstructed digitally using CAD software. The study proved that the structure of constructed tooth was similar to original tooth with minimal error rate. [12]

IX Forensic Facial Reconstruction

Computer aided Forensic Facial Reconstructions are becoming more popular these days. They provide precise information, consume less time and eliminate human errors when done by skilled forensic expert.

The various softwares for post mortem reconstructive identification are Blender, Zbrush, Meshlab, GOM Inspect, Geomagic Free form. [13]

Steps generally involved are [14]:

a. Anthropological assessment of skull

b. Preparation of skull

c. Data acquisition

d. Positioning of landmarks/ soft tissue pegs

e. Anatomic modelling (facial templates can be used)

f. Production of reconstructive face

g. Rendering and finishing

h. Exporting reconstructed face file.

X. 3D printing and Scanning

3D printing is known to be of clinical importance but with the innovations in technology, 3D printing can be explored in the field of forensics as well. Specific laser sintering could be utilized for printing items from polymers such as polyamide, alumide, glass filled polyacrylamide, metals, rubber like polyurethane. [15] The digitalized scans can themselves be used for 3D digital comparison of the suspects teeth using software. The types of 3D scanners used are FASTSCAN, Arctec, Next Engine, GOM Scan, Full space etc. [16]

Conclusion

Recent technological breakthroughs have given up new avenues for resolving cases based on applied features of forensic odontology. The usual forensic investigation of collecting and evaluating data has been changed by digitalization. To summarize, computer-generated photographs are more dependable, accurate, and error-free. The technologies are particularly beneficial in disaster victim identification, where a large number of bodies have been gravely mutilated, as they allow for the digital transfer of photos without loss of information. These new advancements must be adopted and put into action in a lawful and effective manner during forensic investigations. Such technologies will become a fundamental part of the investigation process in the next generation. Though at present, the cost of the digital equipment is high but as technology advances it shall reduce with regular upgrade and utilization in various domains of forensic odontology.

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