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Computer Aided Dental Identification: A New Era in Forensic Dentistry

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Abstract

Forensic odontologist have taken several leaps in recent years to simplify the diversity of dental characteristics to facilitate comparison and identification of individuals particularly following a mass disaster. The first reported computer-aided dental identification system, Dental Identification Package was described by Kogon et al in 1974. Siegel et al (in 1977) proposed quantifying dental characteristics by giving weight to each in a changeable algorithm. This was followed by the introduction of Computer Assisted Postmortem Identification (CAPMI) program by Lorton et al which leads to publication of several programs with different matching philosophies. These computer programs have been assisting forensic odontologist in identifying victims of mass disasters by producing possible matches. This paper describes the different dimensions of computer application in Forensic dentistry.

Keywords: Dental Identification Package; Disaster Identification; Computer-Aided Anti-Mortem Identification Systems; Forensic Dentistry.

Introduction

Disaster is defined as a sudden occurrence that exceeds the resources available in a community to deal with followed by a large number of fatalities [1]. The importances of victim identification is recognized and valued worldwide. The victim identification will not only resolve legal and social predicaments but also it provides a resolution to grieving families [2]. The disaster victim identification (DVI) was globally formalized by Interpol in 1984 with the production of the first DVI manual [3]. Although fingerprints and DNA matching can result in an excellent matching and identification but they are affected by early tissue decay and are not always suitable for identification However teeth are capable of withstanding extreme conditions making them a good choice for identification in the cases involving advanced decomposition [4].

Forensic odontologists have attempted to simplify the diversity of dental characteristics to facilitate comparison particularly following a mass disaster [5].The first reported computer-aided dental identification system: Dental Identification Package (DIP) was described by Kogon et al. in 1974 [6]. Siegel et al (1977) proposed quantifying dental characteristics by giving weight to each in a changeable algorithm [7] followed by the introduction of Computer Assisted Postmortem Identification (CAPMI) program by Lorton et al [8] which leads to publication of several programs with different matching philosophies [9]. These computer programs have been helping forensic odontologists in identifying victims of mass disasters by producing possible matches. In a study conducted by van der meer et al (2010), computer-aided dental identification allows for an objective comparison of antimortem–postmortem radiographs and can be a useful tool to support a forensic dental identification. In 2009 flint et al [11] evaluated a computer-based method for comparing digital dental images, utilizing a registration algorithm to correct for variations in projection geometry between images prior to a subtraction analysis. A numerical assessment of similarity was generated for pairs of images. Using

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well-controlled laboratory settings, the method was evaluated as to its ability to identify the correct specimen with positive results. A subsequent clinical study examined longitudinal radiographic examinations of selected anatomical areas on 47 patients, analyzing the computer-based method in making the correct identification based upon a threshold level of similarity. The results showed that at a threshold of 0.855, there were two false negative and two false positive identifications out of 957 analyses. Results showed that the threshold level of concordance will vary with the anatomical region of the mouth examined. This method may provide the most objective and reliable method for postmortem dental identification using intra-oral images.

There are several computer-aided postmortem identification systems. CAPMI and Win ID are the most famous among these systems. However these systems do not provide high level of automation such as feature extraction, coding and image comparison are still carried-out manually. Moreover the dental codes used in these systems only capture artificial dental work. ADIS (Automated Dental Identification System) is a process automation tool for postmortem identification that is being designed to achieve accurate and timely identification results with minimum amount of human intervention. The ADIS will not only automate some of the steps taken by forensic experts to examine missing and unidentified persons cases but it will be intelligently analyzing radiographs to utilize underlying image structures that are often difficult to be assessed merely by visual examination [12].

ADIS [13] is Composed of Three Main Components

Dental Records Processing Component

It involves several segmentation and classification steps in order to isolate each tooth and determine their class. The search and retrieval component manages the archiving, searching and retrieval of dental matches in order to produce a list of matches. The desirable features of this stage are speed and accuracy.

Potential Search Matching Component

This component extract the high level dental features and stores it in the DIR and then it retrieves a list of candidate images for every subject image. In extracting high level features there are two methodologies adopted in ADIS. The first one focuses more on contour of roots and crowns that are usually important periapical images. The second methodology focuses on extracting the contour of each individual tooth in bite-using images.

Image Comparison Matching Component

It registers and compares two sets of dental records and is used during the search process. In this component the radiograph images is processed through four main stages, enhancement, segmentation, alignment and matching. The enhancement stage removes noise and enhance the quality of the radiograph images, Segmentation stage automatically segments the dental image into rectangular regions where each region independent of orientation, scale and translation. These regions are then matched through a neural network based matcher.

Computer Aided PM Identification System CAPMI and Win ID

These are most well known systems. However the dental codes used in this system are entirely based on characteristics of the dental work and not the inherent dental features. The computer assisted postmortem Identification System [14] was developed by the bioengineering branch of the US Army Institute of Dental Research . CAPMI is the computer software program that compare between dental codes extracted from anti-mortem and postmortem dental records. The program generates a prioritized list of candidates based on the number of matching dental characteristics. This list guides forensic odontologist to reference records that have potential similarity with subject records. The odontologist then completes the identification procedure by visual comparison of radiographs. WinID [12] is a computer system that matches missing persons to unidentified persons using dental and anthropometric characteristics to rank possible matches. Other Information on physical appearances, pathological findings and anthropologic finding can also be added to the database of WinID. The dental codes used in WinID are extension of these used in the CAPMI. However none of these systems provide the desired level of automation as they require a significant amount of human intervention as in both CAPMI and WinID coding and image comparison are carried out manually. Moreover dental codes used in these systems are entirely based on dental work. Hence CAPMI and WinID are more like sorting tools that help to cut down the time of forensic experts.

Automatic Construction of Dental Charts

This methodology presented a dual-stage approach. For the automatic construction of dental charts using appearance based features and string matching in which each segmented tooth (bitewing / periapical film) is independently classified based on teeth reconstruction in two / four image subspaces established using PCA [6]. The literature in this area has shown only shape-based techniques. Shape-based techniques need accurate feature extraction. The tooth contour extraction is a very computational time consuming step. So having an appearance based technique that can solve the problem with the same performance in less than 7 % of the required processing time is a plus. This technique is the first to classify teeth into four classes MPCI (i.e. Molar, premolar, Canine, Incisors). This enhances the subsequent labeling stage. They made use of film-type classification step. In bitewing films, they reduced the four class problem to two. This enhances the initial classification performance for these films.

Hierarchical Dental X-Ray Radiograph Matching

This methodology present new technique for dental X-Ray radiograph matching. The technique uses a hierarchical edge matching algorithm at different resolution. During searching, Matching scores are features extracted from the antimortem and postmortem teeth[15]. This technique has two main stages: feature extraction and teeth matching. At feature extraction stage, the tooth contour is extracted and a distance map is built for each antimortem tooth in the database. At teeth matching stage given a postmortem query image, the distance calculated between the anti-mortem tooth distance map and postmortem tooth, contour at different resolution levels is used as hierarchical structure. The advantage of this technique is that the search space is reduced significantly as well as the computational load. This technique uses the chamfer matching algorithm.

Automated Dental Recognition in MSCT Images

This methodology describes a multi-stage technique to classify teeth in Multi-slice computed Tomography (MSCT) images. The algorithm consists of three stages i.e. segmentation, feature extraction and classification [16]. The segmentation of teeth based on previous experiences in feature extraction they introduced a multi-resolution method using wavelet - Fourier descriptor (WFD), Hosntalab et al combined the benefits of multi-resolution representation and fourier shape representation using wavelet Fourier Descriptors . The centroid distance based shape signature has been used for the derivation of descriptors. WFD coefficients as feature vectors also used for classification. Teeth classification is performed by a conventional supervised classifier. For teeth identification they employ a feed forward neural network classifier with one hidden layer was trained by employing 50 % of teeth in the data set to discriminate different teeth from each other.

One of the challenges to matching radiographs is the disparate projection geometry between the images. Hubar [17] utilized computed dental radiography in a simulated forensic case to replicate the antemortem film angulation and concluded that deviations in conventional bitewing radiographs by as little as five degrees horizontally made identification difficult.Wenzel [18] evaluated a subtraction program based on positioning of reference points in two dental images with that of manual superimposition of the images during video capture. The reference point method required the use of computer algorithms for translation, rotation and perspective distortion to achieve the best overlap of images. The reference point method was found to be superior to manual superimposition for all angulations evaluated. Bowers [19] used a computer-based program to rotate and resize digitized images in an attempt to create identical horizontal orientations of the cemento-enamel junctions of the teeth for the antemortem and postmortem evidence. The postmortem images selected for analysis was chosen as that most closely approximating the tooth angulation seen in the antemortem image. After orientation of cemento-enamel junctions, the postmortem image was then moved onto the antemortem image for a shape comparison evaluation. They concluded that the ability to digitally resize radiographs would allow the investigator to measure and superimpose physical dental features seen in the ante-mortem and postmortem radiographs thus facilitating in cases with few dental restoration. Lehmann [20] studied the use of similar measures for dental subtraction imaging. Most subtraction analyses involve sequentially acquired radiographs utilizing fixed mechanical aids for identical projection geometry of the area of interest. In assessing digital free-hand subtraction radiographs, the radiographs must be adjusted for all possible differences in projection angulations. Lehmann evaluated eight mathematical measurements of image similarity that could be used for the quality assessment of different registration methods for digitized images including the cross covariance coefficient (CCC). In digital image processing, the CCC is well known as a bias-independent measure for two-dimensional discrete

data [21]. All eight measures had been used in medical or dental fields either for assessing pairs of radiographs or to compute an automated image alignment. The measurements obtained were normalized to a range of zero to one, with one indicating a perfect image similarity. Lehmann tested 172 radiographs taken with varying projection angles of a human mandible. Following registration, two images would be considered identical if they contained the same gray level values at all points within the registered image. Two completely different radiographs with no overlapping regions should be zero. Lehmann noted that as a result of system noise, two images will never be identical even with constant projection geometry and exposure factors. In this study he found image similarity and registration are inversely related with the degree of image similarity increasing with decreasing registration error between two images. Of the eight measurements he concluded that in digital free-hand subtraction radiography the CCC is an appropriate computer algorithm to qualitatively compare different means of automatic alignment of x-ray images. Aamad et al [22] concluded that DAVID and WinID3's performance was less accurate by comparison with the more time consuming classical manual matching method. Although both programs have different methods of matching ante-mortem and postmortem dental characteristics, the difference between DAVID and WinID3 was not significant. At the present time computers can assist with the initial sorting of records with confirmation made by manual method.

Dental Charting

This is one of the oldest methods for dental identification which involves comparing dental profiles of the given dentitions. Dental profiles are dental charts which are completed by forensic odontologist [22]. The chart records for each tooth individually for various distinctive features like tooth present/absent, crown, root morphology, dental restorations etc. The comparison involves preparing dental chart of the dentition in question and comparing this chart with those in a database. However this method becomes very complex and is very time consuming.

Comparative Dental Identification using Radiographs

Digital radiography which is used for a decade or more by radiologists has recently become the solution of choice in mass casualty situations. Here comparison is done by forensic odontologists by manually comparing the anti-mortem and postmortem radiographs. It follows a semi-automatic process of matching the radiographic dental images for human identification. For this, they extract shapes of the teeth from both anti-mortem and postmortem images and compare these extracted shapes. The comparison results are based on the distance between the shapes [24].

Conclusion

Since the induction of computers in forensic dentistry, the deceased identification in mass disasters, criminal cases and murders have become more comprehensive and legal. With the use of computers, the individual identification can be assured with more precision than manual technique. In coming years, as the technology is advancing the digital identification of individuals or deceased will become more precise and authentic.

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