REVIEW ARTICLE

Forensic Odontological Parameters as Biometric Tool: A Review

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Abstract

Human identification by virtue of dental identification is on the increase in the past few years and has served as a major adjunct in the identification process. The science associated with the dealing of evidences from dental, oral, and paraoral structures—Forensic Odontology, is a boon in itself. It has been seen that the role of forensic odontology has increased as most of the times teeth and other orally associated structures remain the only means of identification in the worst of scenarios where the conventional biometrics such as fingerprint, iris scan, palm print, etc., may be lost and are therefore not reliable enough to resolve the purpose of identification. There are various important aspects in forensic odontology which are associated with the study of tooth prints, i.e., ameloglyphics, radiographs, the study of palatal rugae patterns, i.e., rugoscopy, cheiloscopy, i.e., the study of lip patterns, tongue prints which can serve as an important biometric tool to aid in the human identification process. Dental biometrics helps to determine several parameters that serve in the interest of forensics such as type of specimen, population affinity, sex, age, stature, race, and various other individualization factors. So, comparative dental identifications with the help of a biometric recognition system will play a major role in identifying deceased individuals in disasters, crimes, or any other mass tragedies.

Keywords: Ameloglyphics, Biometrics, Cheiloscopy, Dental biometrics, Forensic odontology, Radiographs, Smile, Tongue prints.

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Introduction

The word "Biometrics" is devised from the Greek words "bios" for life and "metron" for measurement. Therefore, biometric technologies are defined as the "automated methods of identifying or verifying of a living person based on a physiological or behavioral characteristic".[1] The whole biometric system is based on a pattern recognition system that helps in personal identification and verification by estimating the reliability and the accuracy of various physiological as well as behavioral characteristics owned by the individuals.[1] Biometrics applies cutting-edge technologies to differentiate humans based on their physiological and behavior traits.[1] As it has been that the identification of an individual is becoming very important these days and biometrics play a pivotal role in it.

Biometric Characteristics[2]

Universal

There are various individualistic characteristics or attributes that are possessed by every person which must be universal and very rarely are lost or impaired in scenarios such as an accident, a disaster, or a disease.

Consistency of Properties

These biometric characteristics must remain constant over a progression of time and must not cause remarkable changes based on age, illness either episodic or chronic.

Accessibility

The characteristics such as valuable measurements should be convenient to capture without any waiting time and the attribute data must be easily gathered passively.

Uniqueness

Each expression of a particular character must be unique to an individual which should have unexceptionable unique properties to distinguish one individual from another.

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Acceptability

The data must be obtained in such a manner that is accepted by the maximum of the population without involving any invasive technologies, i.e., technologies which would demand an individual's part of the body or might cause any impairment to their body part.

Minimization

The data which are captured should be capable of being concise into a file that is handy and easily manageable.

Reliability and Tamper-proof

These characteristics should be speculative to any kind of manipulation and should not be masked. It must ensure authenticity, accuracy, and reproducibility.

Privacy

The privacy of an individual should not be violated. It should be purely confidential.

Comparable

It must be able to make it digitally comparable to others with its ability to reduce the attribute as an when required. The identification is more authoritative if less probabilistic the matching is involved.

Idiosyncrasy

The attribute must not be reproducible by any other means. It should be irreproducible. If the attribute is less reproducible, it is more likely to be authoritative.

The field of biometrics has received a lot of attention in the past few years because it being an interesting alternative to traditional authentication systems such as passwords. It basically refers to a characteristic which is a measurable anatomical, physiological, and/or behavioral characteristic whereas as a process it refers to an automated method of recognizing individuals through their biometric characteristics.[3] The main aim of forensic odontology is to identify individuals who may be deceased individuals using their dental characteristics features. This was considered important because under severe circumstances like fire accidents, plane crashes, and natural disasters, in criminal investigations, or in cases of decomposed and disfigured bodies, human identification is beyond recognition, conventional means biometric system involving fingerprints, iris scan may fail to rule out the identification because of their low resistance. Dental structures are considered the best candidates to help in the process of identification in such scenarios. Since the dentition can withstand high temperature, forces, therefore, can serve as a great boon as a biometric tool in the field of forensics. There are various important aspects in forensic dentistry such as tooth prints (ameloglyphics), rugoscopy, dental radiographs, cheiloscopy, tongue prints which can serve as the biometric tool to aid in human identification.

Tooth Prints[4,5]

The peculiar patterns known as enamel rod end patterns present on the tooth surface are referred to as tooth prints. Ameloblasts lay down the enamel rods in an undulating and intertwining path residing onto the outer surface of enamel as a series of adjacent enamel rods. These patterns henceforth formed on the surface of enamel are called tooth prints each of which comprises the combination of further eight different subpatterns, and every which is unique for every single tooth. This characteristic of uniqueness of the tooth print can serve as a significant biometric tool in forensics for identification purposes.

Verification and identification are the two main classifications of automated biometric. In verification, there is peer-to-peer comparison, the biometric tool information of a person with a unique identity is compared with the biometric information of the concerned individual in the database.[5] The comparative analysis obtained determines the identity of an individual either by his/her acceptance or rejection whereas in identification (one-to-one comparison), a comparison is done between biometric information obtained with information from the group of individuals that is stored in the database. To identify an individual's uniqueness based on biometric data it should be:[4,5]

- Different for every individual, i.e., it should be unique.
- Easy to obtain and manipulate.
- There should not be any significant change over the passage of time.
- Easily transferable.
- Able to be obtained as non-intrusively as possible.
- Differentiation by any individual without any prior training.

The main advantage of this procedure is that there are three consecutive tooth prints of every tooth which show similarities in the patterns of enamel rod ends as well as of minutiae points which predicts a particular pattern for each tooth. However, despite such standardization, variations, such as inclusion or deletion of even a single cluster of enamel rods lead to variance in the minutiae score which again adds to the uniqueness of that particular tooth.[4,5]

Radiographs

Various radiographic dental features such as distinctive shapes of the tooth, restoration, root canal treatment, leftover root stumps, bases under restorations, root morphology, sinuses, and jawbone patterns can be appreciated well on radiographs.[3] Original antemortem dental radiographs are of utmost importance for comparison purposes; therefore, it becomes very essential for various routine radiographs taken during the course of dental treatment of a particular patient to be mandatorily documented and preserved both in the manual as well as digital forms. Since no two radiographs will be the same for any individual, these can be stored in an authorized database for metric analysis of the various anatomical features.

Dental Identification System[6]

Following are the various components of the dental identification system are:

- Dental Radiograph, i.e., IOPARs, OPGs, etc.
- Radiograph pre-processing and segmentation.
- Contour extraction.
- Atlas registration.
- Matching of Radiograph.

Dental radiographs of patients are obtained for the dental identification system. These radiographs are first pre-processed to filter out undesirable background present along with the teeth. Then, these radiographs are segmented for the region of interest. The tooth contours present on the radiograph are then extracted using an active contour model. Atlas registration enables labeling or numbering to the teeth present in the jaw which helps in the matching stage. Radiograph obtained from the database is selected, undergoes pre-processing, segmentation and further contour extraction is done from it. Also, teeth registration is given as per atlas registration. And then comes matching, in which an algorithm is used to compare the features from these two radiographs and this matching distance between radiographs obtains the final result of identification of an individual.[6]

Measurements can be made on the following parameters on radiographs which will vary from individual to individual:[7]

- Total number and arrangement of teeth (missing teeth, spacing, rotated teeth, crowded teeth, mobile and impacted teeth).
- Extent of caries and periodontal disease associated with bone loss.
- Metric evaluation of the positions of posts, implants, root canal fillings.
- Maxillary sinus, frontal sinus, and nasal aperture.

Smile as a Biometric Tool

Smile is a universal characteristic that is unique for every individual. Various parameters of smile can be set for metric analysis like:

- Distance between the two commissures (angles of the mouth).
- The intercanine distance can be measured.
- Mesiodistal dimensions of all anterior teeth can be measured.
- Cervico-incisal measurement.
- Midline diastema or spacing can be considered.
- Tooth morphology with respect to any tooth anomaly, rotations, crowding can be taken into consideration.

Since all these parameters will vary in every individual, is universal, measurable, easily acceptable by the population, fulfills all characteristic requirement of a biometric tool that can be used as an adjunct for the identification process in the field of forensics.

Rugae Patterns

These are the irregular, asymmetric ridges of the mucous membrane that extends from the incisive papilla laterally and the anterior part of the mid palatine raphe. These patterns have served as an adjunct in forensic implication because of their high resistance to trauma and their apparent uniqueness in appearance. They remain unchanged and do not undergo any alteration in cases of any thermal or chemical action, any disease, or trauma. The morphological and anatomic position of rugae patterns inside the mouth remains well protected from such insults because they are well surrounded by lips, cheeks, tongue, buccal pad of fat, teeth, and bone. Hence, can be a great boon in forensic identification.[8] Various studies have proven that rugae patterns remain unaffected by tooth eruptive changes or any tooth loss and their patterns as per shape size and direction vary for every induvial. They remain consistent even after the decomposition changes up to 7 days after death. The palatal rugae can be reproduced exactly on the same site even if they undergo any impairment or destruction due to any trauma. All such characteristics make the rugae patterns highly individualistic. These findings were inferred through various studies conducted previously by Hermosilla et al.,[9] Dhoke and Osato,[10] and various other authors. Thus, rugae can be used as an excellent biometric tool which can resolve the purpose of identification. And to use this landmark as an additional tool for identification is dependent on maintaining an antemortem record of palatal rugae patterns which could be in the form of existing dental casts or photographs too.

Lip Prints

Two Japanese scientists namely Tsuchihashi and Suzuki had been investigating forensic odontological relations of the female lips and lipstick.[11] They inferred that the morphology of the lip grooves was specific to every individual. Lips were divided into four quadrants and classification was devised comprising six different types of groove patterns. They illustrated that no two lip prints are alike, which further was confirmed by Tsuchihashi, who did a study on 1,364 individuals and their families. He found that the lip prints remain unchanged over a period of time. He inferred that no two uniovular twins possess identical lip print patterns. He also found that in case of any trauma to a lip, the groove pattern regained its shape after healing.[11,12]

Based upon the above researches, it was inferred that the patterned arrangement of the grooves onto the red part of human lips are highly peculiar and unique for every individual which further leads to the conclusion that these arrangements of furrows on the lips can be used in the process of identification of an individual.[11,12] Standard geometric measurements can be performed for these furrows which can be used in lip biometric systems. Therefore, the same way fingerprints, tooth prints, lip prints can also be used as a biometric tool in forensics since every individual's lips would have a specific pattern and varying measurements.

Recently, there was a study proposed by Rachana et al. in which he devised a methodology using brute force algorithm for pattern matching which was meant for clearly reading the lip print.[12] Henceforth, there are so many biometrics techniques that together can serve as perfect means of human identification and verification. First, a lip print image is compared with the stored database which can then be used either for authentication or identification in various criminal cases or can also be clubbed with many other authenticated techniques of biometrics to support a robust human identification system.[12]

Tongue Prints

The tongue is a pivotal muscular organ that is well encased within the oral cavity to protect the environment. It has some specific and typical characteristic features which vary from one individual to another and even between identical twins. The shape, color, and surface characteristic features present over the tongue reveal visible differences between one individual and another thereby making it a useful tool in personal identification. This is another new personal identification method that can be possible by recording the lingual impression which incorporates unique tongue print patterns which can serve as a method of biometric authentication.[13]

A Hong Kong Polytechnic University-based study in 2007 related to the development of the tongue image database, which recorded both the geometric shape of the tongue and its surface textures, i.e., three-dimensional analysis of the tongue could be possible which was could be an important resource for analysis, assessment, comparison, and evaluation of various tongue print patterns.[14]

Digital software has been formulated which autocorrects the positional alterations and camera conditions along with the color and the hue and then analyzes the tongue for its color and surface texture to match with its database to rule out the positive identification. Many studies have been researched into preparing a proper algorithm for tongue image analysis.[13,15] Other methods tried were videography of tongue and extracting images from the same for it being a non-rigid organ. Other alternate methods that include sublingual vein analysis, are too one of the methods that help in tongue diagnosis.[13,16] The use of tongue prints as a biometric authentication tool is still under research, and studies have found it to be an effective means of identification as compared to other biometric tools.[13]

Conclusion

Biometric authentication is a method of personal identification that has gained popularity in recent years. Biometric authentication is associated with the comparison of the input sample against a sample template which is all manifested in the form of a database to identify the person.

Various modes of biometric systems have already come into existence such as fingerprint, skin color, iris scan, palm

print, document analysis, voice, and face recognition which have served a lot in the process of identification. But, in cases of severe circumstances like that of mass disasters, highly mutilated bodies, burnt cases, or decomposed or skeletonized bodies these conventional biometric tools may be lost or not be significant to be relied upon whereas human oral dentition including teeth, rugae patterns, tongue are durable and survive in all conditions, the tooth is the last thing to decay, burnt, or loss in any form and remains well protected in the severest of all conditions. So, dental features can be used as excellent biometric tools to rely upon since it fulfills all the characteristic requirements of a biometric system and also resolves the purpose of identification in the field of forensic odontology. For this, we need to have an access to secured antemortem databases of all the varying dental features which can be stored for future comparisons and identification purposes. As for now, nothing of this sort has been established in India, but this is the need of today's time and should be implemented and taken into the consideration as soon as possible.

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