ORIGINAL ARTICLE

Ameloglyphics: A possible forensic tool for person identification following high temperature and acid exposure

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Abstract

Introduction: Forensic odontology is a branch that is evolving over time and has opened newer avenues that may help in the identification of individuals. Tooth prints are the enamel rod end patterns on tooth surface and they are considered as a hard tissue analog to fingerprints. Teeth have the highest resistance to most environmental effects like fire, desiccation, and decomposition, and may be used as a forensic evidence. **Aims and Objectives:** The aim of the study was to evaluate if the tooth prints could be used for an individual's identification and reproducibility and permanency of these tooth prints after exposing the teeth to acid and various degrees of temperature. **Materials and Methods:** 90 tooth prints from 20 freshly extracted maxillary premolar teeth were obtained. Cellophane tape technique was used to record enamel rod end patterns on tooth surface. Ten teeth (one from each patient) were immersed in 36.46% hydrochloric acid and the tooth prints were obtained at various intervals (5 min, 10 min, and 20 min). The other 10 teeth (one from each patient) were incinerated and impression was made at various intervals (80° C, 400° C, 600° C, and 750° C). Tooth prints obtained from different teeth (total of 90 tooth prints) were analyzed using Verifinger® standard SDK version 5.0 software. **Results:** All the 20 original tooth prints were distinct from each other and no inter-individual or intra-individual similarity was found. The tooth prints from the same tooth after it was exposed to acid or heat were reproducible and showed high to very high similarity with the original tooth print of that particular tooth stored in the database. **Conclusion:** Tooth prints may be used as an effective aid in person identification even in adverse conditions such as burn and acid attack injuries.

Key words: Ameloglyphics, enamel rod end patterns, forensic odontology, tooth print

Introduction

Human identification is becoming increasingly important in modern life. It may be required in simple procedures such as logging into a computer network or in more complex situations like post-mortem identification and criminal analysis. It is usually achieved by the use of passwords, physical tokens, photographs, iris and dental patterns, fingerprints, and, more recently, DNA analysis.[1]

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Identification of human remains in mass disasters is a difficult task. Identification of burned bodies starts with the identification of objects that have remained with the body, which may not be always readily available. Teeth are considered to be the most indestructible components of the human body. Teeth have the highest resistance to most environmental effects like fire, desiccation, and decomposition. Teeth survive most natural disasters and are a possible tool for personal identification of an otherwise unrecognizable body.[2]

Human dentition is considered hard tissue analog to fingerprints (reliable tools only in a body obtained prior to decomposition or mutilation).[3] Tooth prints is the term used to describe the enamel rod end patterns. Ameloglyphics is the term used for the study of patterns of enamel rods.[4] Enamel does not remodel nor does it remain in close contact with the cells which synthesize it; rather, the ameloblasts retract away from the enamel surface once it has matured and the tooth has erupted. Enamel prisms morphology reflects the morphology of ameloblasts in a species-specific manner. Alterations to the matrix are reflected as defects in the structural organization of enamel.[5] The enamel rod end patterns could be duplicated by various methods, such as using cellulose acetate paper and rubber base impression materials.[4]

The term "biometrics" is used to refer to identification techniques based on physical characteristics. Biometric-based identification and verification methodologies such as fingerprint verification, iris scanning and facial recognition have been used successfully and have improved and refined with automated systems and softwares.[1] These identification methods commonly fail or have certain limitations and may not be efficient when bodies are decomposed, burned, or in cases when only small fragments of calcified tissues are left. However, enamel and dentin of the teeth are highly calcified structures in the body that resist decomposition.[4] Previous *in vitro* studies[4,6] have been done to study the pattern of enamel rod endings on the enamel surface and to investigate if tooth prints patterns could be used for an individual's identification. To our knowledge, none of the studies have evaluated the reproducibility and permanency of these tooth prints after exposing the teeth to adverse environmental condition like high temperature (e.g. in case of burning) and acid exposure (e.g. in case of crime), when the teeth may be used as a diagnostic aid in forensic science comes into play.

Therefore, the present study was designed with an aim of evaluating whether the tooth prints could be used for an individual's identification after exposing the teeth to acid and various degrees of temperature and their reproducibility and permanency.

Materials and Methods

Twenty freshly extracted maxillary premolar teeth were collected from 10 subjects for the study. Teeth with decay, attrition, abrasion, erosion, hypoplasia, fracture and/or restorations were not selected for the study because of the alteration of surface enamel characteristics in such teeth. Two teeth rom each subject were collected for intra-individual comparison. Inter-individual comparison was done between teeth from different individuals. Prior informed consent was obtained from each patient.

All the extracted teeth were scaled and a circle of 5 mm diameter was drawn on the comparatively flat area (middle-thirds) of the labial surface of each tooth. The labial surface of the tooth was ground using high speed air rotor handpiece except for the marked circular area. Ungrounded circular area over the tooth was etched with 37% orthophosphoric acid for 2 min. The etched surface was then washed with water and air-dried. Once the surface had dried a portion of extended cellophane tape was applied over the etched area without any finger pressure. A small piece of cotton roll was applied without pressure for a better adaptation of the cellophane tape. The cellophane tape was then peeled away gently immediately. The cellophane tape was then transferred on a glass slide and observed under research microscope (Olympus CX 21) and a digital image was obtained at X400 magnification. In order to minimize bias during recording of enamel rod end patterns or tooth prints, the following measures were taken: All the photomicrographs were taken at a magnification of X400, the photomicrographs were taken without zooming the camera lens and the photomicrographs hence obtained were cropped to 2000 × 1500 pixels in Microsoft Office picture manager software [Figure 1].

After taking photomicrographs, 10 teeth (one from each patient) were immersed in 36.46% hydrochloric acid. At various intervals (5 min, 10 min, and 20 min), the teeth were taken out of the container and impression of the circular area of the tooth were made by the same method as described earlier. The other 10 teeth (as aforementioned, one from each patient) were exposed to high temperatures in dental casting machine. After achieving the desired temperature, teeth were maintained for 5 min at same temperature and then allowed to cool and impressions were made at various temperature intervals (80^o C, 400^o C, 600^o C, and 750^o C). Photomicrographs of all the tooth prints were taken as described earlier.

The photomicrographs (total of 90) were analysed using Verifinger® standard SDK version 5.0 software to identify enamel rod end patterns called as minutae [Figures 2 and 3; Figure 2 is the photomicrograph with minutae points and Figure 3 is the processed image by the software]. Minutae represent the enamel rod end patterns which may be in the form of discontinuities, end points or empty spaces between two lines.[4] These minutae were analysed by the software to compare the similarity/variability of two patterns. Tooth prints obtained from different teeth (total of 90 tooth prints) were analysed for similarity among tooth prints of teeth of different individuals, among same individuals and among same tooth after exposing it to either temperature (80^o C, 400^o C, 600^o C, and 750^o C) or

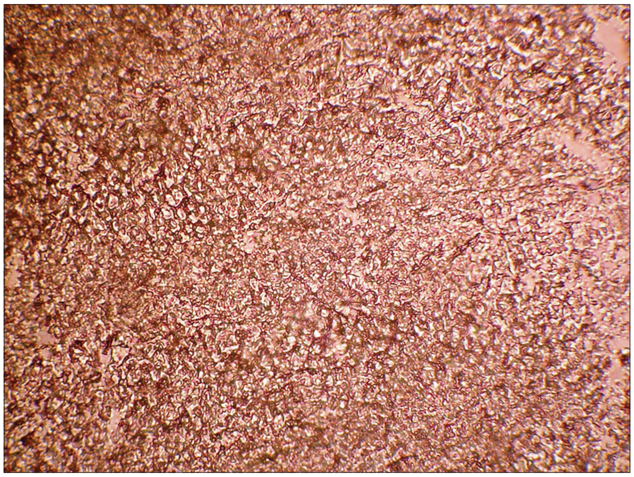

Figure 1: Photomicrographs of tooth print cropped to 2000 × 1500 pixels

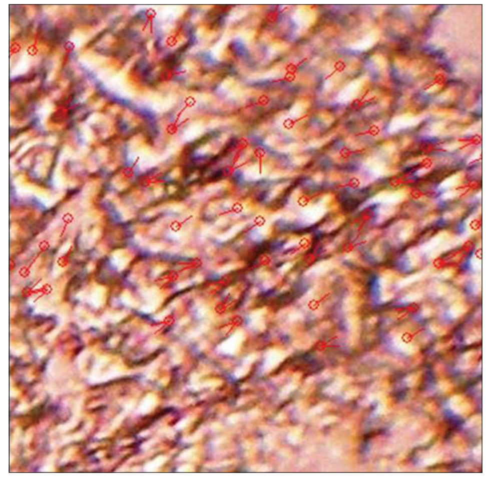

Figure 2: Minutae points marked by the software

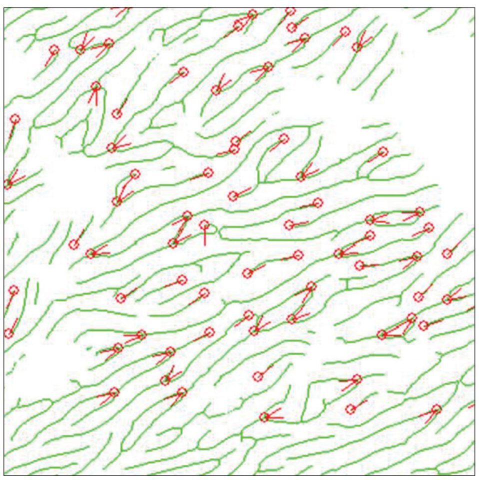

Figure 3: Processed image of tooth print with minutae points

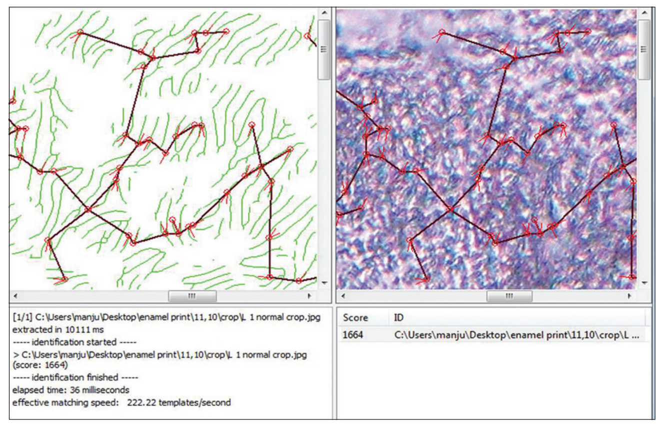

Figure 4: Matching of tooth print with minutae score (showing very high similarity)

acid (5 min, 10 min, and 20 min interval). The software provides a numeral score of similarity (bits). Higher scores are given for more similar characters, and lower or negative scores for dissimilar characters. The similarity scores were divided into four groups as recommended by Ramenzoni *et al*.:[7] group I, 2000-1001 bits (very high similarity); group II, 1000-101 bits (high similarity); group III, 100-10 bits (low similarity); and group IV, 9-0 bits (very low similarity).

Results

A total of 90 tooth prints were obtained from 20 teeth and were analyzed by the software. All the 20 original tooth prints, which were made first, were distinct from each other and no inter-individual or intra-individual similarity was found. The best match (i.e. the highest score) was always achieved when a tooth was compared with itself on the database [Figure 4]. This indicates that toothprint analysis as fingerprint exhibits a high discrimination power and that a toothprint pattern is highly specific, being unique for each teeth of an individual.

The tooth prints from the same tooth after exposing it to acid or heat were reproducible and showed very high to high similarity with the original tooth print of that particular tooth stored in the database.

Discussion

Teeth can be used as a source of evidence in cases of human identification, especially those cases where the soft tissues are unavailable as a possible identification tool.[8,9] The enamel surface presents a variable appearance, exhibiting features such as aprismatic enamel, perikymata, prism end markings, pits and elevations. The basic structural unit of enamel is the enamel prism consisting of several million hydroxyapatite crystals packed into a long thin rod 5-6 mm in diameter and up to 2.5 mm in length. These prisms run from the dentino-enamel junction to the surface.[10] The adjacent enamel rods form a unique pattern due to undulating course of ameloblasts during formative stages.

Such patterns on the surface of enamel are called tooth prints.[4]

In the present study, it was observed that the tooth prints obtained from each tooth were unique, exhibiting dissimilarity both between teeth of different individuals and of the same individual. Previous *in-vitro* studies[4,6] on tooth prints have also shown tooth print patterns to be unique with dissimilarities in both inter- and intra-individual comparisons. This uniqueness of the tooth print could be used as a valuable tool in forensic science for personal identification. The reproducibility and permanency of these tooth prints, even after exposing the tooth to adverse environmental conditions like high temperature and acidic conditions, may be used in cases such as acid attack injuries or exposure to high temperatures, such as in cases of accidents, air crash, bomb blasts and terror acts. Experimental evidence indicates that teeth can withstand much higher temperatures in burned corpses. The preservation of enamel structure is achieved due to the protective effect of the tongue, muscles of mastication, and other soft tissues.[11] Our literature search revealed that there are very few studies that have focused on the positive identification after acid dissolution and destruction of the human body by chemical means previously.

In our study, we attempted to record the tooth prints after exposing the tooth to high temperatures and concentrated acidic solution and their reproducibility and similarity to the original tooth print. Our results showed that tooth prints were obtained at temperatures as high as 750^{o} C and up to 20 min of immersion of tooth in the 36.46% concentrated hydrochloric acid, hence, supporting the application of this technique in the case of burn or acid injury also.

Conclusion

Study of tooth prints is a novel area of research in the field of forensic odontology. The uniqueness of these tooth prints may be utilized as a successful identification tool in forensic science. According to our study, tooth prints appear to be unique to an individual, with dissimilarities between those of different individuals and also the same individual and more importantly these prints are reproducible, even after exposing the tooth to adverse conditions like high temperature and an acidic environment. However, further studies need to be carried out to establish the usefulness of tooth prints as a substantial and unfailing forensic identification tool in cases of acid and burn injuries.

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