Journal of Indonesian Forensic and Legal Medicine
Vol.4, No.2, Agustus 2023, Hal. 396-403
ISSN : 2656-2391

PHOTOGRAPHIC IDENTIFICATION OF TOOTH PRINTS AFTER HIGH TEMPERATURE EXPOSURE

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ABSTRACT

Tooth prints is a very potential tool in forensic identification as the enamel rod patterns on tooth surface is individually unique. This study was aimed to detect changes of tooth prints after teeth were exposed with high temperatures. Forty-five extracted teeth were divided into 5 groups, then exposed to various high temperatures for 15 minutes in a furnace. To ensure practical application, a highly reproducible digital photographic method to detect tooth prints was developed. Before and after the heating process, tooth prints were photographed. The image data was analysed using an open-source biometric software, and the number of matching points of each tooth was compared before and after treatment. Results showed the decreasing number of match points of tooth prints in accord with the increasing of temperature exposure ($P < 0.05$). The number of tooth print matching points can be confidently observed at temperatures 600°C or lower. The consistence of matching points shows the prospect of tooth print analysis to become a reliable identification method. This digital photography technique offers a straightforward method for routine dental recording in daily practice by dentists and identification by forensic odontologists. It opens further direction for standardization of pattern analysis, database development, and daily protocols.
Keywords: dental photography; forensic identification; high temperature; tooth prints

INTRODUCTION

In this century, human identification is increasingly essential to serve for various reasons including legal, humanitarian, and social grounds.[1] Human remains identification often faces obstacles if the evidence is in a decayed or burned condition. Examination of forensic odontology is a very formidable primary methodology, because teeth survive well in such condition. This is related to the typical inorganic composition of teeth and also because teeth are protected by soft tissues and bone.[2,3] The most widely known odontology identification method is dental record examination, although there are other methods that have potential to be developed because the specification feature such as tooth print examination. Tooth print is rod end pattern on enamel surface in the frontal part of the tooth that is estimated to be specific to each tooth and each person.

There is still uncertainty about the permanency of tooth prints after death, especially in conditions after exposure to high temperatures. During fire accident, teeth may be subjected to various high temperatures. The average temperature of a wooden campfire is in the range of 400 to 700°C, house fires is estimated to reach 600°C to 900°C.[4,5] The temperatures of burning vehicles when involving fuel range between 800 and 1100°C.[6,7] Cremation occurs at temperature between 900 and 1000°C,[8] while in volcanic eruptions the temperature of lava ranges between 700°C to 1200°C,[9] compared to natural fire storms which can reach up to 2000°C.[10]

So far, the identification of tooth prints has been relied on the aid of adhesive removable tape, which may hinder further development of tooth prints analysis after heating or burning of the tooth. The aim of this study was to detect changes of tooth prints after teeth were exposed with high temperatures. Moreover, the photographic method developed may opened the possibility to collect high number of tooth prints data, because it is more convenient, sensitive, reproducible, and digitally formed.

MATERIAL & METHODS

Sample

The experiment was perfomed using forty-five teeth, which were collected from routine clinical extraction, consisted of maxillary anterior permanent teeth, 15 central incisors, 15 lateral incisors and 15 canines. Tooth extraction was collected in accord with the research ethics committee. The teeth were collected only from extraction with valid clinical reasons (e.g periodontal disease or orthodontic treatment) in the teaching hospital's dental practice. Teeth with cavity, attrition, abrasion, erosion, hypoplasia, fracture, restoration, endodontic or orthodontic treatment and congenital malformations were excluded. After extraction each tooth washed with distilled water to clean blood and debris. Teeth were soaked in 10% formalin for a week. Formalin (10% concentration) is an effective disinfectant and antiseptic agent for extracted teeth without change in its structure.[11] Then the teeth were placed in saline solution at room temperature. Every two weeks, the solution was renewed until the study begins.[12] All the samples were randomly divided into 5 groups (9 teeth each) according to temperature of exposure.

Exposure to High Temperature

Teeth were exposed to high temperatures in Carbolite furnace ELF 11/6 (Carbolite Ltd., UK) at temperatures of 200, 400, 600, 800, or 1000°C. Furnace was preheated to the designated temperature for 5 minutes. Inside the furnace, teeth were placed in a porcelain crucible and exposed to high experimental temperatures for 15 minutes. Then teeth were removed from the furnace and allowed to cool to room temperature.

Documentation & Analysis of Tooth Prints

Tooth prints were documented by using dental photography technique. The images were taken on the middle third of the labial surface of each anterior maxillary tooth. Before the image was taken, the middle third of the labial surface of tooth was marked using a 2B pencil (before exposed to high temperatures) or thread (after exposed to high temperatures). The images were taken in a mini studio photography with the size of 40 X 40 X 40 cm using Canon EOS 70D (Canon Inc., Japan) DSLR camera; Canon EF 100 mm f/2.8 USM (Canon Inc., Japan) and LED macro ring light device FC 100 5500 K (LED Meike, Hong Kong), which is connected to a computer device.

The teeth were placed in a mini studio with the aid of adhesive removable tape. Photographic equipment connected to a computer device was arranged in such a way that it can be shot through a screenshot of the computer screen. Digital data from tooth image shoots is stored in the computer for further analysis.

Photographic shot of tooth prints resulted in digital images that through a computer screen screenshot were extracted using an open-source biometric-based identification software SourceAFIS (Robert Važan).[13] The software detected the patterns of tooth prints as series of black and white lines in different directions, almost similar to fingerprint. Certain points were used by the software to identify the pattern of each tooth. The software used these points to compare the similarity of two patterns. Two tooth prints obtained from same tooth (before and after heat exposure) were analysed to detect the similarity of points, which termed as matching points. The number of matching points for each tooth in each group was then tabulated.

Statistical Analysis

All data were represented as the mean ± standard error of the mean on each experimental group (n=9). Shapiro Wilk normality tests indicated that all data followed a Levene test ($P > 0.05$); therefore, parametric statistics were applied. Groups were compared using ANOVA and Post-Hoc Duncan test ($P < 0.05$).

RESULT & DISCUSSION

Result

The total of 78 tooth prints were obtained from 39 teeth and were analysed by the software (see Supplementary Figure 1). Six teeth were damaged after being exposed to high temperatures and the documentation on the tooth prints could not be performed.

Tooth print images showed an increasing change in all four quadrants along with higher heating temperatures. The integrity of tooth prints was reduced because of the presence of disconnected line due to the empty space and the missing part (see Supplementary Figure 2). There was a blank space that causes a disconnected line in at least one quadrant. In addition, patterns disappear in at least one other quadrant. Along with higher heating temperatures there was a decrease in the average number of match points of tooth prints between treatment groups ($P < 0.05$, ANOVA Post Hoc Duncan) (Tabel 1). The number of tooth prints match points is more difficult to be observed at temperatures higher than 600°C.

Table 1. Table of average number of tooth prints matching points according to temperature

Note: Asterisks indicate significant differences between groups ($P < 0.05$)

Temperature exposure	Mean ± SD Tooth prints matching points
200°C	10.89 ± 1.764*
400°C	9.22 ± 1.787*
600°C	7.71 ± 1.799*
800°C	6.88 ± 1.727*
1000°C	6.50 ± 1.871*

Discussion

Over the past decade, many researchers in Forensic Odontology have developed dental identification methods using tooth prints. Tooth prints are the enamel rod end patterns on tooth surface.[4] They are unique to individuals such as finger prints; moreover, teeth enamel consists of 96% inorganic material that makes it stand high temperature. Previous studies found that the reproducibility of these tooth prints needs to be evaluated, in order to ensure its practical application and validity. In the previous studies, replication of tooth prints was done by peeling techniques using cellulose acetate or cellophane tape.[14,15] The method was reliable but less practical for casework.

Tooth prints analysis is prospective to mount forensic odontology, since it shows high potential as additional to fingerprint for its specific enamel rod end pattern. Compared to regular dental identification that relies on dental manipulation (dental treatment) and macroscopic morphology, tooth print has potential high specificity which is parallel to fingerprint. This study has demonstrated two important points: the consistence of tooth print pattern after exposed to heat and digital approach of tooth print photography recording.

In this study, we were able to observe clear tooth prints using direct digital photographic method, before and after teeth exposure to high temperature. After being exposed to high temperature, teeth tend to be damaged, especially on the surface of the enamel. The previous studies concluded that after exposure to high temperature, enamel portion of the tooth would experience a number of cracks and fractures.[12,16,17] Tooth enamel has a high content of inorganic material (96%) and low content of organic material and water, which makes it contract and more cohesive among the enamel hydroxyapatite crystalline structure when exposed to high temperature.[3,12,17] Exposure to high temperature is also suspected to cause damage to organic materials in tooth enamel as it burns.[4,8] Hughes and White (2009) stated that rising temperatures also cause the water component to undergo spontaneous evaporation.[18] All of these things cause the crack lines that eventually trigger the occurrence of fractures on the surface of tooth enamel after exposure to high temperature.

The high temperature exposure to the tooth surface directly changed the tooth print. More changes were observed when the temperature was higher, which directly related to the tooth prints match points. Based on the SourceAFIS data we detected decline of matching points in higher temperature exposure, particularly above 600^{o}C, and vice versa. The permanency of tooth prints is strongly influenced by the temperature and duration of heat exposure to the teeth. It can also be seen in several previous studies with similar treatment.[14,19]

During experiment six teeth were damaged after being exposed to high temperatures and the documentation on the tooth prints could not be performed. It is important to know that this experimental study was an *in vitro* study. The effect of high temperature exposure was a laboratory-based simulation. There was no direct fire exposure to the teeth. High temperature exposure was done inside the laboratory furnace. In *in vivo* conditions, the influence of heat temperature may be different. It is influenced by various factors such as the protection of hard tissue and soft tissue around the teeth. Nevertheless, to ensure the suitability of this study, the selected temperature and the method of high temperature exposure were adjusted according to the laboratory-based studies that were previously conducted. Overall, this is a strong indication that heat does not change the pattern of enamel rods, it only reduces the number of match points that can be compared digitally.

In this study, we had developed a digital photography technique to record tooth prints. So far, this study is the first one that used digital photographic techniques directly to replicate enamel surface patterns. This has enabled us to produce digital image, which can be directly cropped on the median part as the observation target area and then analyzed using a biometric open-source software for pattern extraction. Dental photography technique is more straightforward from the previous research that relies on tooth print on cellophane tape followed by microscopic analysis. Our technique is also different from Ramenzoni & Line (2016)[19] that used analog photography which has to be converted first into digital negative image, before it has to be contrasted using image processing application. This method opens the possibility to record tooth print digitally in daily dental practice and stored as a part of an individual dental record. This type of data can easily be used as antemortem data for possible identification in the future.

Digital photography technique used in this study is prevalent for amateur photographers, fast, and cost-efficient, compared to analog photography technique and peeling techniques. DSLR photography has the ability to see focus precisely and frame the image accurately. Effective lighting is the key to success. Natural daylight photography (6540K color temperature) does not strike a balance between the composition of red, green and blue. To capture the texture of the tooth surface, standard lighting is a light source in the form of photographic daylight achieved by using flashlight (5500 color temperature). The light source mounted on the front of the camera is an ideal configuration to capture the texture of the enamel surface, because the light source can be directed to the structure of the enamel surface.[20,21] Thus the microstructure of the teeth can be recorded clearly (see Figure 1A). This can simplify and facilitate the process of taking replicas of email surface patterns.

At least, there are two reasons why fingerprint biometric-based identification software was used in any study on tooth prints. First, because until now there has been no special biometric-based identification software to analyse tooth prints. In addition, tooth print closely resembles fingerprint pattern. This type of similarity has the potential for digitization which will pave the way for digital biometric analysis, such as those used for fingerprints, digital documentation, and barcoding. Further explanation regarding the photography technique used compared to reference is provided in the Supplementary Table.

CONCLUSION

Dental photography of tooth print is very potential to be developed as a reliable identification technique, which possible parallel to fingerprint. According to our study, it can be estimated that the identification process of tooth prints using dental photography is more easily done in the event of exposure to heat with temperatures below 600° C. However, further study should be undertaken to assess the effects of other environmental effects on teeth with respect to the permanency of tooth prints. This study has successfully developed dental photography technique in the documentation of tooth prints, result in a procedure that was more concise and more convenient in practical level.

ACKNOWLEDGEMENT

We would like to thank Fathul Huda, MD, PhD, from the Faculty of Medicine, Universitas Padjadjaran for his support in the photographic technique.

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