ORIGINAL ARTICLE

Reliability of automated biometrics in the analysis of enamel rod end patterns

Manjunath K,
Saraswathi TR,
Sriram G,
Sivapathasundharam B,
Porchelvam S[1]
Department of Oral and Maxillofacial Pathology, Meenakshi Ammal Dental College and Hospital, Chennai; [1]Brainware Biosolutions Ltd, Chennai, India

Address for correspondence:
*Dr. K Manjunath
Department of Oral and Maxillofacial Pathology, Meenakshi Ammal Dental College and Hospital, Alapakkam Main Road, Maduravoyal, Chennai - 600 095, India.
Email: janmu81@yahoo.co.in*
DOI: 10.4103/0974-2948.50887

Abstract

Tooth prints are enamel rod end patterns on the tooth surface. These patterns are unique to an individual tooth of same individual and different individuals. The aim of this study was to analyze the reliability and sensitivity of an automated biometrics software (Verifinger® standard SDK version 5.0) in analyzing tooth prints. In present study, enamel rod end patterns were obtained three times from a specific area on the labial surface of ten extracted teeth using acetate peel technique. The acetate peels were subjected to analysis with Verifinger® standard SDK version 5.0 software to obtain the enamel rod end patterns (tooth prints) and respective minutiae scores for each tooth print. The minutiae scores obtained for each tooth print was subjected to statistical analysis using Cronbach's test for reliability. In the present study, it was found that Verifinger® software was able to identify duplicate records of the same area of a same tooth with the original records stored on the database of the software. Comparison of the minutiae scores using Cronbach's test also showed that there was no significant difference in the minutiae scores obtained (>0.6). Hence, acetate peel technique with Verifinger® standard SDK version 5.0 is a reliable technique in analysis of enamel rod end patterns, and as a forensic tool in personal identification. But, further studies are needed to verify the reliability to this technique in a clinical setting, as obtaining an acetate peel record from the same area of the tooth *in-vivo*, is difficult.

Key words: Automated biometrics, enamel rod end patterns, tooth prints, Verifinger

Introduction

Personal identification is becoming increasingly important in modern life, and regardless of the method, is ubiquitous in our daily lives. Conventionally, personal identification was performed using passports, keys, badges, tokens, access cards, passwords, secret codes, personal identification numbers (PINs), and the like. Unfortunately, passports, keys, badges, tokens, and access cards can be lost, duplicated, stolen, or forgotten; and passwords, secret codes, and PINs can easily be forgotten, compromised, shared, or observed. Such deficiencies of conventional personal identification techniques have caused major problems to all concerned.

On the other hand, certain features of human body are unique to each and every individual and can be used as a tool for personal identification. Such physical or biological measurement pertaining to an individual is termed biometrics. Some frequently used measurements are height, weight, hair color, eye color, and iris[1] and skin colors of an individual. These measurements can aid in describing an individual, but is not specific, as more than one individual can fit such a description. To uniquely identify an individual based on biometric data,[2] it should be

- Highly unique to each individual.
- Easily obtainable.
- Time-invariant (should not undergo any significant change over a period of time).
- Easily transmittable, able to be acquired as nonintrusively as possible.
- Distinguishable by humans without much special training.

Biometrics are being automated to eliminate the need for human verification, and a number of new biometric measurements have been developed, taking advantage of improved understanding of the human body and advanced sensing techniques. Automated biometrics-based personal identification systems can be classified into two main categories: verification and identification.

In the process of verification (one-to-one comparison), the biometric information of an individual, who claims certain identity, is compared with the biometric information of that particular individual in the database. The comparative results determine whether the identity claims shall be accepted or rejected. On the other hand, in the process of identification (one-to-many comparison) a biometric information obtained is compared with information of a group of individuals that is stored on the database.[2]

Advancements in information technology over a decade are directed toward the development of various software applications for the purpose of analysis, storage, and comparison of various biometric measurements. For instance, various software applications are available to analyze finger prints like Sig ID biometric fingerprint software system, M2SYS fingerprint SDK software system, IdentiFi biometric identification system, Verifinger standard SDK, and the like. Verifinger® standard SDK version 5.0 software was developed by Neurotechnologia in 1998, to compare and analyze finger prints. Liza *et al*. used this software for automated biometric analysis of Hunter Schreger bands in enamel for personal identification.[3] In our earlier study, we used Verifinger® standard SDK version 5.0 to analyze the enamel rod end patterns (tooth prints) obtained using acetate peel technique.[4]

As the software Verifinger® standard SDK version 5.0 was primarily designed to analyze finger prints, the reliability and credibility of the software in analysis of tooth prints need to be verified. Hence, the present study was designed to analyze the reliability and sensitivity of automated biometrics system (Verifinger® standard SDK version 5.0) in analyzing enamel rod end patterns.

Materials and Methods

In this present study, extracted teeth with clinically normal crown from ten different individuals were collected. Teeth with decay, attrition, abrasion, erosion, hypoplasia, fracture, and/or restoration were not selected for the study. All the extracted teeth were scaled and polished.

Recording enamel rod patterns using acetate peel technique

In order to avoid error in positioning the acetate film over recording area during serial recordings, a circle of 5-mm diameter was drawn on the comparatively flat area (middle thirds) of the labial surface of the tooth. The labial surface of the tooth was ground using aerotor handpiece except the circular area [Figure 1a]. Ungrounded circular area of the tooth was etched with 10% orthophosphoric acid for 20 seconds, washed with water, and dried; a thin layer of acetone was applied over a small piece of cellulose acetate film and placed immediately over the etched surface of the tooth without any finger pressure for 20 minutes [Figure 1b]. The acetone dissolves a layer of cellulose acetate and the dissolute settles down along the irregularities on the enamel surface. The film is gently peeled after 20 minutes and observed under light microscope. A photomicrograph of the acetate peel is obtained at 40x magnification [Figure 1c]. To assess the reliability of the software, three individual acetate peel recordings were performed on each tooth.

In order to minimize bias during recording of enamel rod end patterns, the following measures were taken:

- All the photomicrographs were taken at a magnification of 40x objective and 10x eyepiece of an Olympus 20i microscope.
- The photomicrographs were taken without zooming the camera lens.
- The circular phomicrographs hence obtained were cropped to 2000 × 1500 pixels in Microsoft Office picture manager [Figure 1d].

Analysis of acetate peel recordings

The cropped photomicrograph was subjected to biometric analysis using Verifinger® standard SDK version 5.0. The software obtains the patterns and subpatterns of enamel rod endings as series of lines running in varying directions, and assigns a specific identification number, minutiae score, and stores the pattern in the database [Figure 1e].

Verifinger® standard SDK version 5.0 uses certain points called minutiae for identification and comparison of various patterns analyzed. Minutiae are discontinuities of lines, line endings, dots, very small lines, ponds, and/or empty spaces between two lines [Figure 1f].

Statistical analysis

Each recording was coded with two-digit alpha-numeric code. The first digit (alphabet) represented the tooth (A, B, … J) and the second digit (numeric) represented recording of the same tooth (1, 2, 3). The minutiae scores of all the three recordings of each tooth were tabulated and statistically analyzed using Cronbach's test. A Cronbach's test reliability score of ≥0.6 represents that two or more values compared were not significantly different, which indirectly means that the two or more recordings are identical to each other.

Results

In the present study, three enamel rod patterns each of ten

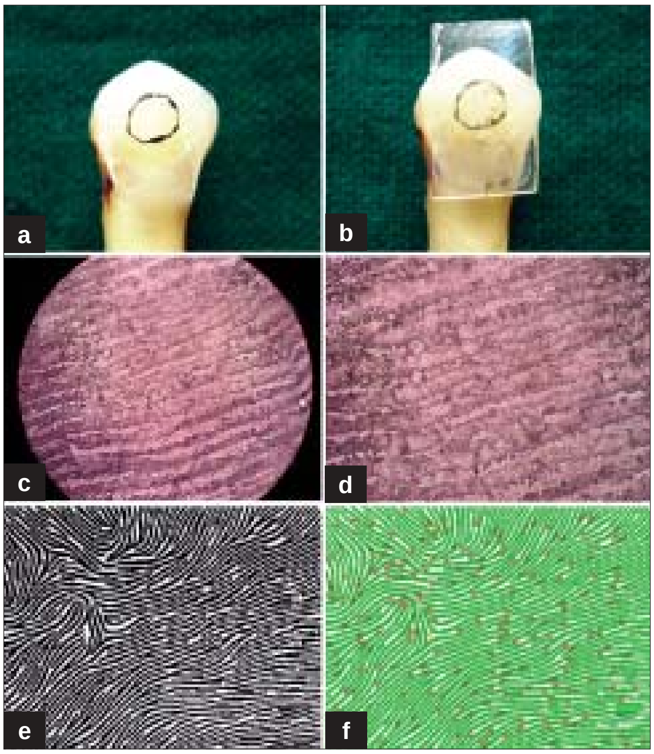

Figure 1: Automated biometrics using acetate peel technique

different teeth were obtained using acetate peel technique, analyzed using Verifinger® standard SDK version 5.0 software. Each tooth print was stored in the database of Verifinger® with a specific identification number and minutiae score [Table 1].

Each tooth yielded a similar pattern of tooth print in all the three recordings, and Verifinger identified each duplicate recording of a tooth to be identical to the original tooth print of that particular tooth stored in the database [Figures 2 and 3].

For instance, if A_1, A_2, and A_3 were the three consecutive recordings of the tooth A. B_1, B_2, and B_3 of tooth B and so forth, then the records,

$A_1 = A_2 = A_3$

i.e., all the three recordings of the tooth A are identical to each other.

$A_1 \neq B_1/ B_2/ B_3 \ldots J_1/ J_2/ J_3$

$A_2 \neq B_1/ B_2/ B_3 \ldots J_1/ J_2/ J_3$

$A_3 \neq B_1/ B_2/ B_3 \ldots J_1/ J_2/ J_3$

i.e., all three recordings of tooth A are not identical to recordings of other tooth.

Even though each duplicate tooth print of a particular tooth was found to be identical, the minutiae scores obtained were not equal.

$A_1 \neq A_2 \neq A_3$ $\quad$ $B_1 \neq B_2 \neq B_3 \ldots$ $\quad$ $J_1 \neq J_2 \neq J_3$

Comparison of the minutiae scores of records 1 and 2 of each tooth using Cronbach's test, showed the reliability score of 0.96. Similarly, comparison of record 2 with record 3, record 3 with record 1, and record 1 with records 2 and 3 yielded reliability scores of 0.98, 0.92, and 0.97, respectively [Table 2]. All the four reliability scores were >0.6, indicating that each duplicate record was identical to the original record of each tooth.

Discussion

Teeth have been extensively used as a source of information in human identification, especially when soft tissue cannot provide reliable information.[5,6] Enamel covering the crown of the tooth, is the hardest biological tissue and while highly mineralized, withstands both shearing and impact forces well.[7] The undulating course of ameloblasts during amelogenesis results in the formation of a pattern by series of adjacent enamel rod ends. These patterns on the enamel surface are called as tooth prints. The study of enamel rod end patterns on tooth surface is termed as ameloglyphics. These enamel rod end patterns could be duplicated by various methods like acetate peel technique, rubber base impression, etc.[4]

In our previous study,[4] we reported the use of Verifinger® standard SDK version 5.0 software for analysis of enamel rod end patterns obtained by acetate peel technique and its application in forensic odontology for personal

Table 1: Minutiae scores of each tooth

	Minutiae scores		
Tooth ID	**Record 1**	**Record 2**	**Record 3**
A	1770	1690	1710
B	1310	1085	1274
C	1640	1447	1528
D	1770	1740	1566
E	1760	1740	1633
F	1240	1175	1073
G	1370	1110	1262
H	1290	1167	1241
I	1572	1533	1418
J	1610	1530	1448

Table 2: Comparison of three records obtained for each tooth

Pattern	Mean	Standard deviation	Reliability score (Cronbach's test)
1	1533.2	211.8	0.96
2	1421.7	265.7	
1	1533.2	211.8	0.98
3	1415.3	200.4	
2	1421.7	265.7	0.92
3	1415.3	200.4	
1	1533.2	211.8	0.97
2	1421.7	265.7	
3	1415.3	200.4	

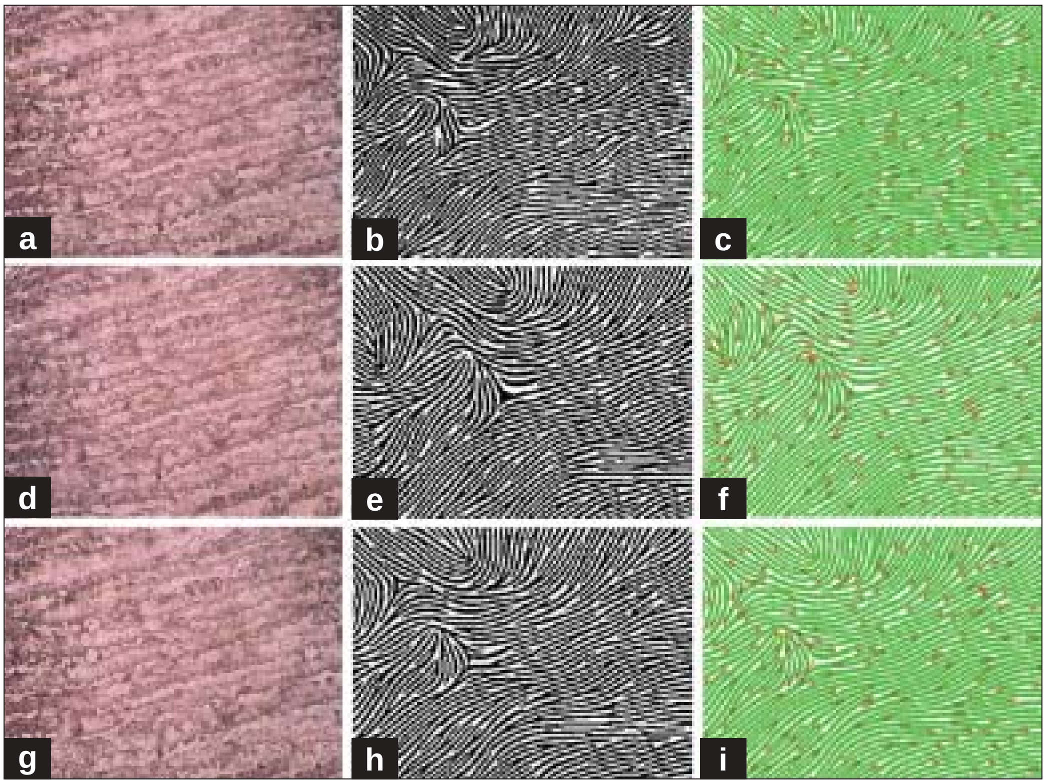

Figure 2: Three successive tooth prints of tooth A. All the three prints show a similar pattern of enamel rod ends (a, d, g and b, e, h), and similar distribution of minutiae points (c, f, i)

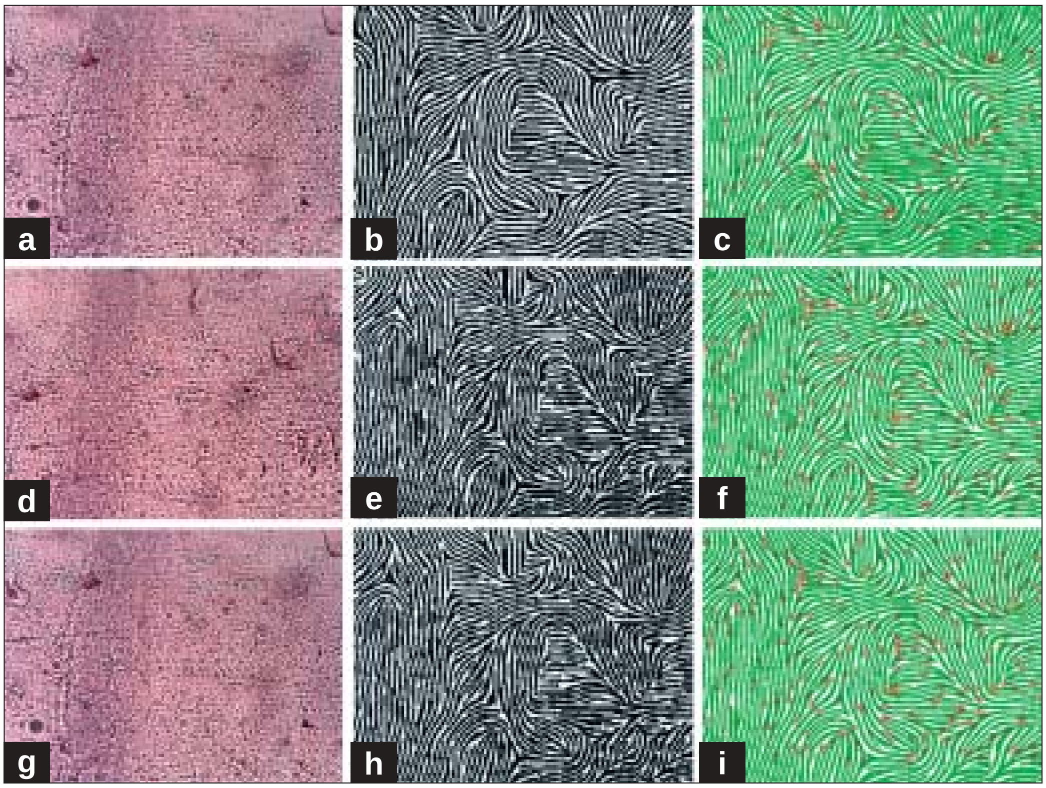

Figure 3: Three successive tooth prints of tooth B. All the three prints show a similar pattern of enamel rod ends (a, d, g and b, e, h), and similar distribution of minutiae points (c, f, i)

identification. In this study, we found that each tooth print was composed of combination of eight different subpatterns, and each tooth print was unique to a particular tooth.[4] This uniqueness of the tooth print could be used as a valuable tool in forensic science for personal identification.

Verifinger® standard SDK software being the software primarily designed to analyze finger prints, the reliability and credibility of the software in analysis of enamel rod patterns need to be questioned. The results of the present study, suggest that Verifinger® could be used with considerable accuracy and reliability in analysis of enamel rod end patterns obtained from a specific area on the tooth surface.

Even though Verifinger® software was able to recognize a duplicate tooth print from the same area of the tooth to be identical to an original tooth print stored in the database, the minutiae scores obtained for each tooth print varied. This could be attributed to the variation in the positioning of the acetate film, variation in the area of the print that was photographed, and variation in the area that was cropped for Verifinger® analysis. All the three factors were taken into consideration and each procedure was standardized to maximum extent possible. In spite of standardization, there can be variation, as inclusion or deletion of even a single cluster of enamel rods, could lead to variation in the minutiae score.

Variation in the minutiae score, does not affect the identification ability of the software, as the software does not take into account the number of minutiae points for comparison. Instead this software uses the distribution and relationship of these minutiae points to each other in a particular area.

Hence, acetate peel technique with Verifinger® standard SDK version 5.0 is a reliable technique in analysis of enamel rod end patterns, and as a forensic tool in personal identification. But, further studies are needed to verify the reliability to this technique in a clinical setting, as obtaining an acetate peel record from the same area of the tooth *in-vivo*, is little difficult.

References

1. Hallinan PW. Recognizing human eyes. Geometr Met Comput Vision 1991;1570:214-26.
2. Shen W, Tan T. Automated biometrics based personal identification. Proc Natl Acad Sci 1999;96:11065-6.
3. Ramenzoni LL, Line SR. Automated biometrics based personal identification of Hunter Schreger bands of dental enamel. Proc R Soc B 2006;273:1155-8.
4. Manjunath K. Enamel rod end patterns: A preliminary study using acetate peel technique and automated biometrics. J Forensic Odontol 2008;1:33-6.
5. Stefen C. Enamel structure of arctoid carnivora: Amphicyonidae, Ursidae, Procyonidae and Mustelidae. J Mammal 2001;82:450-2.
6. Holland MM, Cave CA, Holland CA, Bille TW. Development of a quality, high throughput DNA analysis procedure for skeletal samples to assist with the identification of victims from the World Trade Center attacks. Croat Med J 2003;44:264-5.
7. Berkovitz BK, Holland GR, Moxiham BJ. Oral anatomy, histology and embryology. 3rd ed. Mosby Publication; 2002. p. 110-1.

Source of Support: Nil, **Conflict of Interest:** None declared

Staying in touch with the journal

1) **Table of Contents (TOC) email alert**
Receive an email alert containing the TOC when a new complete issue of the journal is made available online. To register for TOC alerts go to **www.jfdsonline.org/signup.asp.**

2) **RSS feeds**
Really Simple Syndication (RSS) helps you to get alerts on new publication right on your desktop without going to the journal's website. You need a software (e.g. RSSReader, Feed Demon, FeedReader, My Yahoo!, NewsGator and NewzCrawler) to get advantage of this tool. RSS feeds can also be read through FireFox or Microsoft Outlook 2007. Once any of these small (and mostly free) software is installed, add **www.jfdsonline.org/rssfeed.asp** as one of the feeds.