Analysis of enamel rod end pattern for personal identification

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Abstract

Background: Microscopically, groups of enamel rods run in unique direction, which differ from adjacent group of enamel rods and results in forming different patterns of enamel rod endings on tooth surface. These are called as tooth prints and they help in personal identification in forensic odontology.

Aims and Objectives: The aim of the present study is to analyze the enamel rod end pattern on the tooth surface for personal identification and to analyze the familial inheritance of enamel rod end pattern.

Materials and Methods: In the present study, 100 different families were considered for the analysis of tooth print pattern. In each family, four members were present. The maxillary central incisor, canine and first premolar were selected. Enamel rod end pattern was recorded using acetate peel technique and analyzed using Verifinger® standard SDK version 6.7 software.

Statistical Analysis: Data analysis was performed using the SPSS software. Contingency coefficient statistical analysis was used for the comparison of tooth print pattern in incisors, canines and premolars based on age and gender. $P < 0.05$ was considered statistically significant.

Results: The present study showed that a tooth print is composed of combination of eight distinct subpatterns, namely wavy branched, wavy unbranched, linear branched, linear unbranched, whorl open, whorl closed, loop and stem-like pattern. Wavy branched pattern was found to be the most predominant pattern in incisors, canines and first premolars in our study. Familial tendency of tooth print pattern in incisors, canines and premolars was noticed in 65%, 66% and 52% of the families, respectively.

Conclusion: Tooth prints are unique to an individual and can be used as a valuable inexpensive tool in forensic odontology for personal identification.

Keywords: Enamel rod end, peel technique, tooth prints

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INTRODUCTION

Identification of an individual is a challenging task in the present world. The most commonly used methods for identification in forensic science include the photographs, iris and dental patterns, fingerprints and DNA analysis.[1] However, these identification methods cannot be used when the bodies are burned or decomposed.[2] Teeth have been used as a reliable tool for personal identification in

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forensic medicine, especially when the soft tissues cannot provide adequate information.[3]

Amelogenesis refers to the formation of enamel by ameloblasts and is a highly organized process. The ameloblasts secrete enamel in such a way that the enamel rods have an intertwining path. This is reflected on the outer surface of the enamel as series of enamel rod end patterns. The study of patterns of enamel rods is known as ameloglyphics (amelo meaning enamel and glyphics meaning carvings).[4] Both genetic and environmental factors influence the process of odontogenesis and amelogenesis. The size, shape and color of the enamel may be inherited from the parents.[5,6] The individualization of tooth print can be attributed to variations in environmental factors surrounding each developing tooth. This includes the position of the developing tooth bud, temperature, pressure or nutrition to the ameloblasts. Genetics might also have a role in predetermining the type of pattern.[7]

The tooth prints are unique, exhibiting variations between teeth of different individuals and of the same individual. This uniqueness of the tooth print could be used as a valuable tool in forensic dentistry for personal identification. Analysis of tooth prints is best suited for personal identification for individuals working in dangerous occupations such as fire fighters, soldiers, jet pilots, divers and people who live potentially unstable areas. In 1998, Neurotechnologia developed VeriFinger SDK identification software for biometric system integrators. Originally, this software was used for fingerprint analysis, but it can also be used for tooth print analysis. VeriFinger SDK (v5.0, Neurotechnology, Lithuania, European Union) software is a reliable biometric tool for the analysis of enamel rod end patterns in ameloglyphics.[3]

The aim of this study is to assess intra- and interpersonal variations in enamel rod end pattern of teeth and to analyze the familial inheritance of enamel rod end pattern.

MATERIALS AND METHODS

The study was approved by the institutional ethics committee. Before initiating the study, written informed consent in accordance with the ethical codes adopted by the National Committee for Medical Research Ethics was given by all the participants. Participants of both genders were selected from 100 different families by simple random sampling. Patients with intact teeth were included in this study. Patients with a history of orthodontic treatment, teeth with abrasion, erosion or caries in the cervical region, teeth with developmental defects or restorations and fractured teeth were excluded from the study. The patients were thoroughly examined and a detailed case history was taken from each participant.

The enamel rod patterns in the middle third of the labial or buccal surface of the maxillary right central incisor, canine and first premolar were analyzed. The tooth was isolated and dried. Once the surface had dried, a drop of acetone was applied over a small piece of cellophane sheet film and placed immediately over the surface of the tooth without any finger pressure for 2–3 min. The acetone will dissolve a layer of cellophane sheet and the dissolute will settle down along the irregularities on the enamel surface. A small piece of cotton roll was applied over the cellophane sheet for a better adaptation. The film was gently peeled after 3 min. The portion of the cellophane tape was cut and transferred on a glass slide and observed under a light microscope in low-power magnification. The imprint area was focused and was photographed. These photomicrographs were subjected to biometric analysis using VeriFinger® standard SDK version 6.7 software. This software recognized the patterns of enamel rod endings as series of lines running in varying directions. The software used certain points called minutiae for identification of each pattern. These minutiae were used to compare the similarity/variability of two patterns.

The patterns of tooth prints were compared between individuals of the same family and between different teeth in the same individual. Tooth print patterns were categorized as linear branched, linear unbranched, wavy branched, wavy unbranched, whorl open, whorl closed, loop and stem-like pattern according to Manjunath *et al*.[2] Each enamel rod end pattern had a combination of few subpatterns, but was predominated by a single subpattern.[2,3]

Statistical analysis

Data analysis was performed using the SPSS (version 17.0, IBM, New York, USA) software. Contingency coefficient statistical analysis was used for the comparison of tooth print pattern in incisors, canines and premolars based on age and gender. $P = 0.05$ was considered statistically significant.

RESULTS

The present study showed that a tooth print is composed of combination of eight distinct subpatterns, but was predominated by a single subpattern. The subpatterns were wavy branched, wavy unbranched, linear branched, linear unbranched, whorl open, whorl closed, loop and

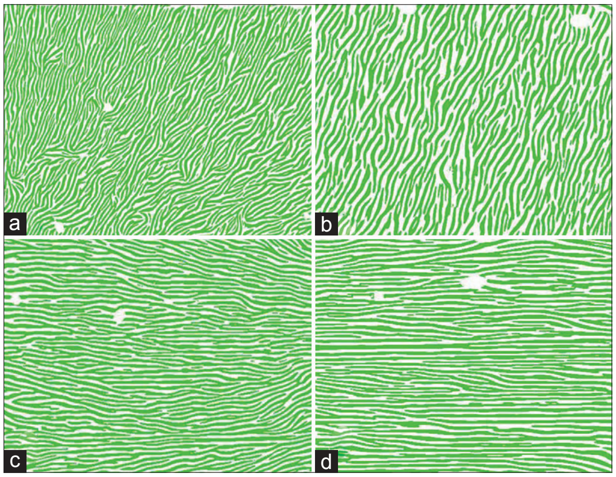

Figure 1: Enamel rod end patterns: (a) wavy branched, (b) wavy unbranched, (c) linear branched and (d) linear unbranched

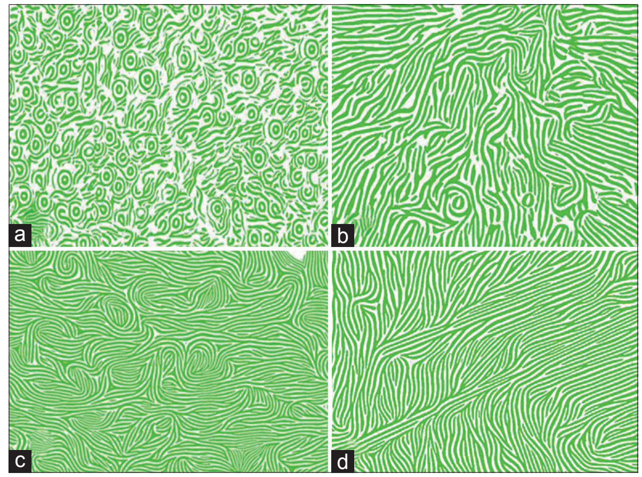

Figure 2: Enamel rod end patterns: (a) whorl closed, (b) whorl open, (c) loop pattern and (d) stem-like pattern

stem-like pattern [Figures 1 and 2]. Wavy branched pattern was found to be the most predominant pattern in incisors, canines and first premolars in our study. The distribution of enamel rod end patterns in males and females is shown in Tables 1-3. Comparison of enamel rod end patterns in incisors, canines and premolars based on gender was statistically significant ($P = 0.00$). Familial tendency of tooth print pattern in incisors, canines and premolars was noticed in 65%, 66% and 52% of the families, respectively.

DISCUSSION

Dental identification is considered to be one of the most reliable methods of identifying an individual in forensic odontology. The antemortem and postmortem records of the individual are compared for congenital and acquired characteristics of the teeth. Teeth are highly resistant to environmental effects such as fire, desiccation and decomposition, and hence, they are considered to be the most indestructible components of the human body.[8,9]

Enamel forms the outermost component of tooth crown and is the hardest substance in the human body. Microscopically, enamel consists of groups of enamel rods running in different directions. This difference in direction results in formation of different patterns of enamel rod endings on the tooth surface.[10,11] From the surface of enamel, these rod endings can be lifted as a tooth print. The study of such patterns of enamel rod endings is referred to as "ameloglyphics."[12] Studies have shown that the enamel rod end pattern is unique for each tooth in an individual.[7]

In this study, acetate peel technique was used for obtaining tooth prints. The peel-making technique was first developed by palaeobotanists to study the cellular structures of fossil plants.[13] Füsun *et al.* used acetate peel technique to study dental structures in three-dimensional view. This study was done on fully mineralized enamel without routine decalcification.[14] Manjunath *et al.* compared the efficacy of cellulose acetate film, cellophane tape and light body impression material in recording enamel rod endings on tooth surface and concluded that cellulose acetate film is a reliable material for recording enamel rod endings on tooth surface.[3]

Table 1: Distribution of enamel rod end pattern in incisors among males and females

Enamel rod end pattern	Males, *n* (%)	Females, *n* (%)	Contingency coefficient	
			C	*P*
Wavy branched	63 (32.0)	119 (58.6)	0.38	0.000
Wavy unbranched	37 (18.8)	17 (8.4)		
Linear branched	50 (25.4)	9 (4.4)		
Linear unbranched	14 (7.1)	32 (15.8)		
Whorl open	6 (3.0)	11 (5.4)		
Whorl closed	11 (5.6)	4 (2.0)		
Loop	7 (3.6)	9 (4.4)		
Stem like	9 (4.6)	2 (1.0)		

Table 2: Distribution of enamel rod end pattern in canines among males and females

Enamel rod end pattern	Males, *n* (%)	Females, *n* (%)	Contingency coefficient	
			C	*P*
Wavy branched	80 (40.6)	122 (60.1)	0.24	0.001
Wavy unbranched	11 (5.6)	13 (6.4)		
Linear branched	59 (29.9)	31 (15.3)		
Linear unbranched	16 (8.1)	18 (8.9)		
Whorl open	4 (2.0)	5 (2.5)		
Whorl closed	12 (6.1)	3 (1.5)		
Loop	11 (5.6)	10 (4.9)		
Stem like	4 (2.0)	1 (0.5)		

Table 3: Distribution of enamel rod end pattern in premolars among males and females

Enamel rod end pattern	Males, *n* (%)	Females, *n* (%)	Contingency coefficient	
			C	*P*
Wavy branched	81 (41.1)	114 (56.2)	0.26	0.000
Wavy unbranched	21 (10.7)	26 (12.8)		
Linear branched	63 (32.0)	25 (12.3)		
Linear unbranched	16 (8.1)	26 (12.8)		
Whorl open	3 (1.5)	0 (0.0)		
Whorl closed	5 (2.5)	3 (1.5)		
Loop	7 (3.6)	8 (3.9)		
Stem like	1 (0.5)	1 (0.5)		

In the present study, VeriFinger software was used for analyzing the tooth prints. Each time when a tooth print was subjected to biometric analysis using VeriFinger®, the software obtained the patterns and subpatterns of enamel rod endings and stored the pattern in the database. Whenever the tooth print obtained from the same tooth was subjected to biometric analysis the second time, the software identified each duplicate recording of a tooth with the use of minutiae. Tooth print obtained from one particular tooth did not match with the print obtained from another tooth of the same individual or from another individual. Manjunath *et al.* assessed the reliability and sensitivity of VeriFinger® standard SDK version 5.0 in analyzing tooth prints. The results of the study showed that the software was able to identify duplicate records of a same tooth comparing with the original records that is stored on the software database. The authors concluded that VeriFinger® is a reliable software for analyzing enamel rod end.[15,16]

Gupta *et al.* compared the tooth prints of different individuals and different teeth of the same individual. They showed that none of the enamel rod end patterns exhibited intraindividual and interindividual similarity. The authors also concluded that no specific class of tooth could be preferentially used for assessing rod end patterns.[12] Joshi *et al.* assessed the pattern of enamel rod endings using automated biometrics and showed similar results.[17] A study done by Raju *et al.* showed that enamel rod end patterns were specific for an individual and also specific for a particular tooth.[5]

The present study showed that a tooth print is composed of combination of eight distinct subpatterns, but was predominated by a single sub pattern. The subpatterns were wavy branched, wavy unbranched, linear branched, linear unbranched, whorl open, whorl closed, loop and stem like as described by Manjunath *et al.*[2] Three distinct subpatterns, namely linear branched, linear unbranched and wavy branched, were described by Joshi and Bhosale[17] whereas Dahal *et al.* observed patterns such as straight, wavy, branched, looped, intersecting and radiating.[7]

According to our study, wavy branched pattern was the most predominant pattern in incisors, canines and first premolars. Our result is similar to the studies done by Manjunath *et al.* and Raju *et al.*[5,16]

In the present study, 100 different families were considered for the analysis of tooth print pattern. In each family, four members were present. Of these 400 individuals, 203 were female and 197 were male. Comparison of enamel rod end pattern in incisors, canines and premolars was significantly different between males and females ($P = 0.00$). Raju *et al.* studied distribution of enamel rod end patterns in males and females. However, no significant difference in tooth print pattern was observed between males and females.[5]

Familial tendency of tooth print pattern in incisors, canines and premolars was noticed in 65%, 66%, and 52% of families, respectively. None of the study on ameloglyphics has reported the familial tendency of tooth print pattern till date.

The enamel rods follow a tortuous course from the dentinoenamel junction to the surface tooth. This may result in different rod end patterns at varying depths even in the same tooth. Rod ends are generally very prominent in newly erupted teeth. The enamel surface is always subjected to both micro- and macrowearing and processes such as attrition, abrasion and erosion wear the outermost layer of enamel rod ends and expose the underneath layer. This could further change the enamel rod end patterns with time. Manjunath *et al.* conducted a study to determine the thickness of enamel showing similar enamel rod end patterns. They also estimated the average time taken for change in enamel rod end pattern due to tooth brushing. The study showed that each enamel rod end pattern takes approximately 4–6 years to change into the subsequent pattern due to *in vivo* brushing. Therefore, it was suggested that the enamel rod end pattern should be recorded for at least every 4 years.[4]

CONCLUSION

Ameloglyphics can play a significant role in personal identification of individuals particularly working in dangerous occupations such as soldiers, divers, jet pilots and people who live and travel to potentially unstable areas. However, the enamel rod end pattern should be recorded for at least every 4 years during its practical application.

Ameloglyphics is a simple inexpensive technique that can be used as an adjunct method in the personal identification. Future study with a larger study group is recommended to establish the familial inheritance of enamel rod end patterns.

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Conflicts of interest

There are no conflicts of interest.

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