ORIGINAL ARTICLE

Scanning electron microscopic analysis of incinerated teeth: An aid to forensic identification

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ABSTRACT

Background: Forensic dental identification of victims involved in fire accidents is often a complex and challenging endeavor. Knowledge of the charred human dentition and residues of restorative material can help in the recognition of bodies burned beyond recognition. **Aim:** To observe the effects of predetermined temperatures on healthy unrestored teeth and different restorative materials in restored teeth, by scanning electron microscope, for the purpose of identification. **Materials and Methods:** The study was conducted on 135 extracted teeth, which were divided into four groups. Group 1-healthy unrestored teeth, group 2-teeth restored with all ceramic crowns, group 3-teeth restored with class I composite resin and group 4-teeth restored with class I glass ionomer cement (GIC). **Results:** The scanning electron microscope is useful in the analysis of burned teeth, as it gives fine structural details, requires only a small sample and does not destroy the already fragile specimen. **Conclusion:** Scanning electron microscope can be a useful tool for the characterization and study of severely burnt teeth for victim identification.

Key words: Forensic identification, healthy unrestored teeth, restorative materials, scanning electron microscope

INTRODUCTION

Human identification by forensic odontological analysis is a well established and reliable method.[1] Forensic odontology in particular has been seen to be useful when damage has been caused by heat.[2]

Fire remains one of the major causes of morbidity and mortality throughout the world and identification of a body from the fatal fire remains a daunting task.[3] Norrlander classified body burns into five categories: (1) superficial burns (2) destruction of epidermal areas (3) destruction of the epidermis, dermis and presence of necrotic areas in the underlying tissues (4) total destruction of the skin and deep tissue and (5) burnt remains.[4]

Identification of burnt bodies starts with the objects that have remained with the body. Teeth are considered to be the most indestructible components of the human body and have the highest resistance to most environmental effects like fire, desiccation and decomposition because of their particular resistant composition and protection by soft tissues. Teeth survive most natural disasters and provide a positive personal identification of an otherwise unrecognizable body.[5] As the destruction of the burnt victims of the third, fourth and fifth categories is extensive, such remains cannot be identified by conventional methods like visual recognition or fingerprints. In these cases, the odontologists are called to assist in identification.[6]

In recent years, tooth-colored restorative materials consisting of composite resins, glass ionomer cement (GIC) and ceramic crowns are being used in both the anterior teeth as well as posterior teeth and are becoming far more prevalent due to the trend of replacing metal alloys by other materials that can reproduce the closest appearance of the original teeth. Therefore, the chances are great that an individual who is treated at a contemporary dental practice will have at least one type of these materials in the mouth.[5]

The combinations of healthy and restored teeth is said to be as unique as a fingerprint. This uniqueness allows for dental comparison to be a legally acceptable means of identification.[7] Most features of damage to the oral tissues and dental restorations can be observed directly by the naked eye, but electron microscopic investigation can be very useful for two main reasons: to identify the changes that the dental tissues have undergone in order to estimate the temperatures

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Quick Response Code:

Website: www.jomfp.in

DOI: 10.4103/0973-029X.131889

they were exposed to and to characterize the different types of dental treatments.[8]

The purpose of this study was to observe the scanning electron microscopic (SEM) changes of healthy unrestored teeth exposed to predetermined temperatures of 200, 400, 600, 800 and 1000°C. To study various restorative materials, SEM observations were made on restored teeth at 1000°C temperature in order to determine whether at that temperature any finding could be possibly significant in using forensic analysis.

MATERIALS AND METHODS

In the present study, 135 extracted teeth, disinfected in a 5% sodium hypochlorite solution for 1h, were divided into four groups. The three most common tooth-colored restorative materials used were ceramic, composite resin and GIC.

Group 1: 75 teeth; free from any pathology. (A set of 15 teeth each subjected to predetermined temperatures of 200, 400, 600, 800 and 1000°C).

Group 2: 15 teeth with all ceramic-fixed crown prosthesis. (Ceramco II material, India).

Group 3: 15 teeth with class I composite resin restoration (Esthet. X HD, Densply, India).

Group 4: 15 teeth with class I GIC restoration (GC Gold Label Glass Ionomer Universal restorative, India).

Erosive, hypoplastic, fractured and/or previously restored extracted teeth were excluded.

To avoid experimental or measurement bias, restorative material were filled in determined dimensional class I cavities in premolars (5 × 3 × 3 mm) and molars (3 × 2 × 2 mm). The approximate dimensions of the restoration were measured by 'William's Probe'.

After restoration, all samples including healthy teeth were stored in 0.9% sodium chloride solution at room temperature for 1 month to simulate oral cavity conditions before further tests.

Healthy unrestored tooth sample was placed in a custom-made tray of phosphate-bonded investment material and exposed to burnout furnace at five different predetermined temperatures-200, 400, 600, 800 and 1000°C-reached at an increment rate of 30°C/min, whereas restored tooth was exposed to 1000°C.

Once the desired temperature was reached, the teeth samples were maintained inside the furnace for 15 min, after which they were removed and left to cool to room temperature. Thus, all the teeth samples were exposed to the elevated temperatures for a short standardized period of time.

Each burnt tooth sample was coated with an ultrathin, electrically conductive material, i.e. gold. This material was coated on the sample by low vacuum sputter technique. Then the tooth sample was examined by SEM under ×1000 magnification.

RESULTS

SEM analysis of healthy unrestored teeth

Enamel

At 200°C, enamel displayed superficial changes confined to a few small crazing patterns. At 400°C, the crazing lines were more numerous and more pronounced at the level of cementoenamel junction. Crazing pattern and cracks developed and multiplied with the rise in temperature, leading to chequered look of the enamel at 600°C. At 800°C a few zones with a molten appearance was noted, which appeared shrunken and smaller as the temperature rose. The enamel fragments that became consistently smaller with increase in temperature, however, presented with the typical prismatic structure and thus could be recognized even at 1000°C.

Dentine

At 400°C, dentine revealed a slightly crazed pattern. At 600°C, dentine showed reduced diameter of dentinal tubules, which was a sign of elevation in temperature. At 800°C, debris was noted covering the dentinal tubules. The dentinal structure became consistently smaller and appeared to be covered by granules, which gave a molten appearance to the structure at 1000°C.

Cementum

At 200°C, cementum showed small crazing pattern. At 400°C, the crazing lines were more numerous and more pronounced at the level of cementoenamel junction. At 600°C, crazing pattern and cracks developed and multiplied over cementum with some zones revealing the underlying dentine. Teeth continued to crack near the cementoenamel junction, leading to a honeycomb appearance of these zones at 800°C. At 1000°C, cementum was not identifiable as only vesicular-shaped granules were observed [Figure 1 and Table 1].

SEM analysis of restored teeth

At 1000°C, ceramic crowns showed numerous bubbles on their surface. Composite and GIC fillings were dislodged from the cavities and showed charred remains of restoration, those of composite being pink and GIC being black in colour. Instrument marks on the floor and walls of the cavities, made during tooth preparation were seen very clearly with SEM [Figure 2 and Table 2].

DISCUSSION

The establishment of forensic odontology is an unique discipline that has been attributed to Dr. Oscar Amoedo (Father of Forensic Odontology), who identified the victims of fire accident in Paris, France in 1897.[6]

Dental identification is one of the most reliable and frequently applied methods of identification and forensic odontology is a specialty in itself. In forensic odontology, a great deal of effort goes into identifying the victim. One method of identification is to examine the burned bodies and their fine traces, as well as to examine the resistance of teeth and restorative material exposed to high temperature.[3]

Bodies may be subjected to various temperatures during fire accident. House fires seldom reach temperatures of 1200°F (649°C), whereas cremation occurs at temperatures between 871-982°C[5] and combustion of petrol between 1600-1800°F (800-1100°C).[9] The temperature reached in many fires also depends on the site (open or closed environment), the nature of the oxidant, the duration of combustion and the substances used to extinguish the fire as well as the burning atmosphere that may have a considerable effect on the tooth and its restorations.[9]

SEM examination of healthy unrestored teeth was carried out from 200 to 1000°C. At 200°C, first structural changes were seen on enamel and cementum that presented as small crazing pattern. As the temperature rose, enamel, dentine and cementum structure decreased and became smaller in size. At 1000°C, enamel structure became consistently smaller but presented the typical prismatic structure, which was well appreciated even at that temperature. Cementum, however, was not identifiable at this high temperature, as it appeared as vesicular-shaped granular structure. These changes seen in tooth structure at different temperatures can alone or in combination contribute toward positive identification of a victim.

SEM analysis of restored teeth was carried out at 1000°C. At this temperature, ceramic crowns showed numerous bubbles on their surface. Restorative materials showed deposits of charred residues of restoration on the floor and peripheral surfaces of cavity. Charred remains of GIC restoration were black and that of composite restoration were pink in color. Teeth with dislodged restorations showed empty cavities with instrument marks on the floor and walls of the cavities made during tooth preparation. Therefore, different colored charred remains of restoration and instrument marks on the floor and walls of the cavities could be of some value in victim identification process in severely burnt cases.

As this was an *in vitro* study, it could not simulate the exact *in vivo* circumstances present in real life, i.e. protection

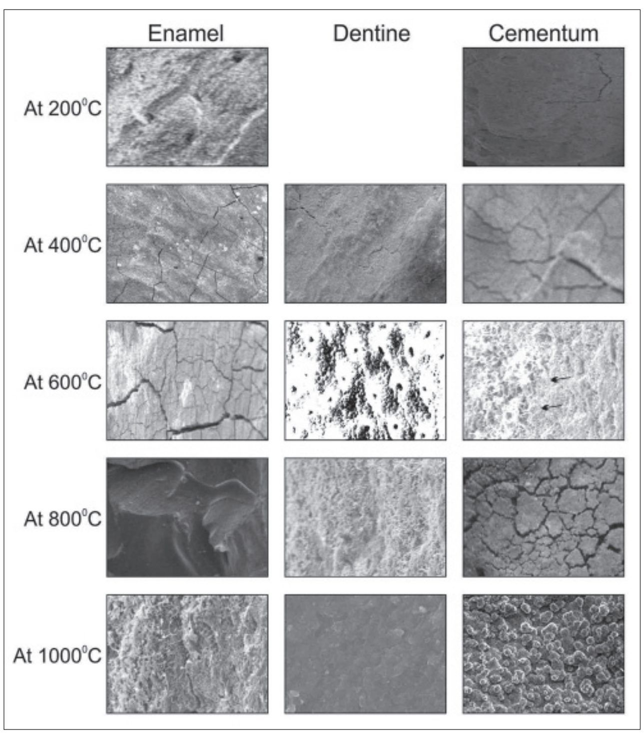

Figure 1: Scanning electron microscope (SEM) analysis (×1000) of healthy unrestored teeth subjected to elevated temperatures (Group 1-healthy unrestored teeth)

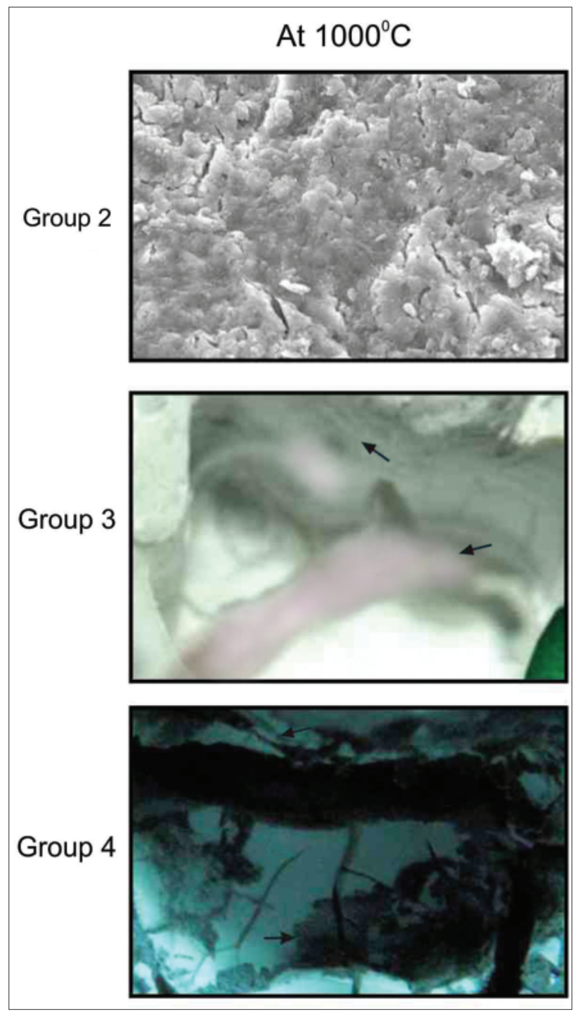

Figure 2: SEM analysis (×1000) of restored teeth subjected to extreme temperature (Group 2-all ceramic crowns, Group 3-composite restoration and Group 4-Glass Ionomer Cememt)

Table 1: SEM analysis of healthy unrestored teeth

Temperatures	Healthy unrestored teeth
200°C	Enamel and cementum showed small crazing pattern
400°C	Dentine revealed a slightly crazed pattern. Crazing lines were more numerous and more pronounced at the level of cementoenamel junction
600°C	In enamel, crazing pattern and cracks developed and multiplied rapidly with the rise in temperature leading to a cracked mud or chequered appearance. Dentine showed reduced diameter of dentinal tubules. Crazing pattern and cracks developed and multiplied over cementum with some zones revealing the underlying dentine
800°C	Enamel, dentin and cementum structure decreases and became smaller in size. Molten appearance of enamel was seen and debris was noted covering dentinal tubules. Hexagonal "honeycomb" structure makes the cementum difficult to recognize
1000°C	Enamel structure became consistently smaller with increase in temperature but presented the typical prismatic structure. Dentine appeared to be covered by granules, which gave a molten appearance to the structure. Cementum was not identifiable as only vesicular-shaped granules were observed

SEM: Scanning electron microscope

Table 2: SEM analysis of restored teeth

Temperature	All ceramic	Composite	GIC
1000°C	Numerous bubbles on the surface of ceramic crown	Cavity showed instrumental marks and a deposit of charred (pink) remains of the restoration	Floor of the remnants of cavity showed instrumental marks and a deposit of charred (black) remains of the restoration

SEM: Scanning electron microscope, GIC: Glass ionomer cement

provided by the soft tissues, presence of bone covering the root cementum and so forth. In our study, once the predetermined temperatures were reached, the tooth samples were removed from the burnout furnace and allowed to cool at room temperature. Therefore, the materials were subjected to only controlled thermal shock.

Whenever there is severe damage to teeth and associated structures due to fire, only fragments of teeth remain available for analysis, attached with occasional findings of some restorative material remnants. These severely burnt teeth are fragile, charred or discolored and can go unnoticed in the huge fire debris. Along with macroscopic examination, SEM can be an useful tool to salvage some evidence for identification and analysis.

Our experiment showed that dental hard tissues, prosthetic device and restorative materials undergo a range of changes at different temperatures to which they are exposed. These changes are a consequence of the nature of the materials and their physical/chemical characteristics. Even at high temperatures, teeth are recognizable as they are well-mineralized structures and therefore not completely destroyed. Teeth can thus be of great value in thermal history, to give a clue to understand the chain of events that may have occurred and can contribute in identifying human remains in a mass disaster involving fire.

CONCLUSIONS

When there has been severe damage to teeth and associated structures as a result of fire and conventional means of dental identification are not possible, some evidence may be salvaged by the use of the SEM.

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How to cite this article: Pol CA, Gosavi SR. Scanning electron microscopic analysis of incinerated teeth: An aid to forensic identification. J Oral Maxillofac Pathol 2014;18:32-5.

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