Original Article

Morphologic and Radiographic Changes in Teeth and Restorations Subjected to High Temperatures

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ABSTRACT

Context: In fire accidents and cremation, fires may reach temperatures as high as 1150°C. In such circumstances, teeth and bones are the only remains which can help in personal identification, as teeth and restorations are unique to an individual.

Aims: This study was conducted to assess morphological and radiographic appearances of teeth at various high temperatures.

Settings and Design: This was an *in vitro* observational study; 160 extracted teeth were included in the study. The teeth were randomly classified into four groups of 40 teeth each. Teeth in Group 1 were retained without any restorations. A total of 60 teeth were endodontically sealed with zinc oxide eugenol sealer and restored with gutta-percha; coronal restorations were made with amalgam, light cure composite, or restorative glass ionomer cement. Radiographs of all teeth were obtained.

Subjects and Methods: A burnout furnace was used for heating the teeth. Forty teeth each were heated to 200°C, 400°C, 600°C, and 800°C. The teeth and restorations were physically examined, and radiographs of all teeth were again obtained and correlated with the preincineration radiographs.

Results: Teeth showed progressive discoloration from black to white, with the development of cracks and crowns shattered by 800°C. Restoration lost their marginal adaptation. On radiographs, initially, crowns developed fissures, followed by the roots.

Conclusion: This study documented morphological and radiographic changes occuring in teeth when exposed to high temperatures.

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KEY WORDS: *Dental materials, incineration, personal identification, radiographs*

INTRODUCTION

In the field of natural and man-made disasters, fire has played a predominant role. Fires cause 1% of the global burden of disease.[1] An estimated 180,000 deaths every year are caused by burns.[2] Death rates due to fire in India are 4.68/100,000 population in 2014, as per WHO.[3] Owing to industrial, technological, and military development, as also to the increasing number of armed conflicts, there has been a rapid change in the modalities and numbers of burn injuries.[4]

Several communities cremate their dead bodies. Cremation takes place at a temperature of 760°C–1150°C and results in the reduction of all tissues to ashes except bones and teeth. Under these circumstances, identification of an individual from the remains is always difficult because of the serious damage and/or disintegration of the bodies of the deceased.[5]

Teeth often survive severe fires because of their particularly resistant composition and also the protection given by the soft tissues of the face. Teeth are also unique to an individual in terms of number, arrangement, and dental treatment received. However, teeth and restorations undergo changes when exposed to fires depending on the temperature reached, the situation (open or closed surroundings), the oxidant's nature, the duration of combustion, and the action of different fire extinguishing products used.

Radiographs of teeth are a component of most patients' dental records and are considered definitive evidence in court. Radiographic comparison exploits the matching of corresponding features at two levels of anatomical complexity – external shape and internal architecture. They show the location, shape, and unique characteristics of each restoration and may also reveal distinctive shape of teeth and roots.[6]

Thus, a combination of morphologic and radiographic evidence would greatly enhance identification. Thus, it is important to study the effect of heat on intact teeth and teeth restored with different restorative materials clinically and radiographically.

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Subjects and Methods

One hundred and sixty intact freshly extracted teeth were included in the study. The teeth had been stored in normal saline after extraction.

The teeth were randomly classified into four groups of 40 teeth each, as given in Flowchart 1 below. Teeth in Group 1 were retained without any restorations. Twenty teeth each in Groups 2, 3, and 4 were endodontically sealed with zinc oxide eugenol sealer and restored with gutta-percha (Dentsply, Maillefer) by the lateral condensation technique. All 40 teeth in Group 2 were coronally restored with amalgam (DPI Alloy, India). All 40 teeth in Group 3 were coronally restored with light cure composite (Charisma by Kulzar). All 40 teeth in Group 4 were coronally restored with restorative glass ionomer cement (GIC). All restorations were made following the manufacturers' instructions.

Radiographs of all the teeth were obtained with a digital charge-coupled device sensor (Sopix radiological imaging system). Size 1 sensor with an active dimension of 600 mm^2 was used. Teeth were stabilized on a block of modeling wax and in turn placed on the sensor. Exposure times of 1, 1.3, and 1.6 s were used for incisors, premolars, and molars, respectively. The images were evaluated on Sopro Imaging Software version 1.20.76 (SOPRO, Acteon group).

A burnout furnace was used for heating the teeth. Ten unrestored teeth, 10 teeth with amalgam restoration (including 5 endodontically restored), 10 teeth with light cure composite (including 5 endodontically restored), and 10 teeth with glass ionomer restoration (including 5 endodontically restored) were heated to a temperature of 200°C. Similarly, 40 teeth each were heated to 400°C, 600°C, and 800°C. The teeth were allowed to cool to room temperature naturally.

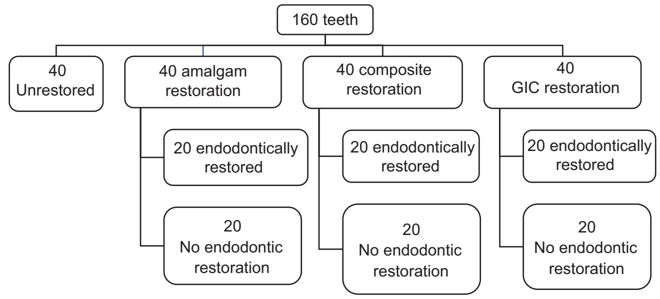
The time taken to reach the target temperatures were noted. The teeth were physically examined by two dentists for integrity, changes in color of the teeth, and restorations if any. Radiographs of all teeth were again obtained and correlated with the preincineration radiographs. The findings were tabulated.

Results

Starting from room temperature, the total time of exposure to heat for each set of specimen was 6.51 min to reach 200°C (392° F); 14.48 min to reach 400°C (752°F); 24.56 min to reach 600°C (1112°F); and 31.47 min to reach 800°C (1472°F).

Table 1 shows the comparison of the physical appearance of crowns and roots of unrestored teeth before and after exposure to higher temperatures. Table 2 shows the changes in the physical appearance of restorations when subjected to higher temperatures. Table 3 shows the radiographic changes in unrestored teeth on heating, and Table 4 shows the changes in the restorative materials on heating to different temperatures.

Particularly, it was recorded that all the unrestored teeth were intact although radiography revealed some alterations within the crowns. After 600°C (1112°F), two teeth showed the detachment of the crown and one of these crowns shattered. After 800°C (1472°F), three teeth had the crown detached, and two of these crowns were shattered.



Flowchart 1: Method of grouping and restoration of teeth

Table 1: Physical changes in unrestored teeth at various temperatures

Temperature (°C)	Crown	Root
200	Crown intact with fissures, loss of translucency of enamel, appearance of shiny surface	Intact root, change in color to black
400	Loss of translucency of enamel, surface appears rough, presence of fissures, fractures in crowns in some teeth, charred dentin	Intact root, no change in color
600	Change in color of enamel, fractures in crown, shattered crowns of few teeth, charred dentin	Intact root, change in color to white
800	Change in color of enamel, shattered crowns reduced to fragments, dentin shows white deposit	Intact root, white colored, with presence of fissures on the surface

Discussion

This study was carried out to assess the morphologic and radiographic changes in teeth and restorations subjected to high temperatures keeping in view that teeth are intact after a fire accident and can yield useful information to identify an individual. Further, the temperatures attained during fire accidents vary and morphological appearance at different temperatures could differ.

Morphological alterations in teeth

Morphological alteration in teeth is shown in Figure 1. Teeth showed progressive loss of translucency with increasing temperature. This finding of our study is similar to that of Savio *et al*. except for the changes seen at 200°C.[6] At this temperature, all teeth were heavily covered with soot. This could be easily removed from the crown surfaces, while it was difficult to remove from root surfaces due their roughness. After scraping off the black soot deposit, a change in color of the crown to brownish yellow at 200°C was noted.

Loss of translucency of enamel has been attributed to loss of water. In human enamel, water exists in two forms: adsorbed

Table 2: Physical changes in restorations at various temperatures

Temperature (°C)	Amalgam	Light cure composite	Glass ionomer cement
200	Loss of sheen, loss of marginal adaptation, color remains unchanged	Loss of marginal adaptation, restoration is blackened	Loss of marginal adaptation, restoration is blackened
400	Loss of sheen, loss of marginal adaptation, color remains unchanged	Loss of marginal adaptation, whitish in color but with darker shade	Loss of marginal adaptation, whitish in color
600	Loss of sheen, loss of marginal adaptation, color remains unchanged	Loss of marginal adaptation, whiter in color	Loss of marginal adaptation, whitish in color
800	Loss of sheen, change in the shape and dimension of restoration, color remains unchanged	Loss of marginal adaptation, whiter in color	Loss of marginal adaptation, whitish in color

Table 3: Differences observed in the radiographic appearance of unrestored teeth at various temperatures

Temperature (°C)	Crown	Root
200	Radiolucent fissures between enamel and dentin	No changes
400	Radiolucent fissures between enamel and dentin and within dentin	No changes
600	Radiolucent fissures between enamel and dentin and within dentin	Radiolucent fissures within root
800	Reduced to fragments	Radiolucent fractures through root

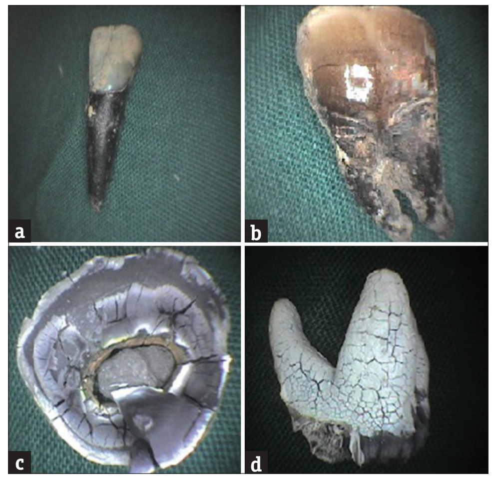


Figure 1: Morphological alterations in teeth (a) teeth covered with soot at 200°C (b) brownish-yellow discoloration of crown at 400°C (c) shattered crown at 800°C (d) intact root with fissures at 800°C

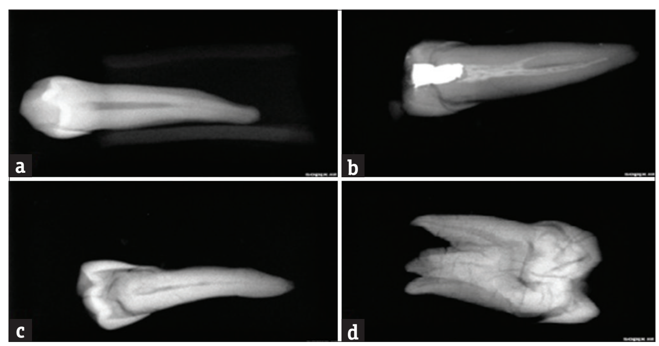


Figure 2: Radiographic alterations in teeth (a) fissures in the crown at 200°C (b) appearance of radiolucent areas in radicular restoration at 400°C (c) radiolucent fissures at 600°C (d) fissures in crown and root at 800°C

water, which is lost continuously and reversibly till 200°C; and lattice water, which is lost irrversibly beyond 200°C with sharp loss at 250°C–300°C.[7] Loss in translucency was steep at 400°C. Further increase in temperature caused mild progressive deterioration in translucency. With increasing water loss, void volume increases proportionately from the initial volume of 0.2% to 5%.[8] These voids, filled with air, cause scattering of light accounting for opacity.[9]

At 200°C, brownish-yellow discoloration of enamel is a manifestation of the altered color of underlying dentin. Although heat-related color changes can be expected in dentin, it is not seen clinically in intact teeth due to opaque enamel. The color change in dentin is caused by the browning of collagen, while the whitening of enamel is due to desiccation. At 400°C, dentin was charred and was visible through the areas of cracks. Sakae *et al*. stated that mineralized dentin showed an exothermic peak at about 310°C and the combustion of organic materials was completed at about 450°C. This renders the dentin to remain black at higher temperatures. It is also shown that exothermal peak of mineralized dentin is much lesser than demineralized dentin due to the interference of apatite crystals in cross-linked collagen fibers. Hence, color of dentin after subjecting to different temperatures could be a function of mineral content.[10]

Our study showed minor linear cracks at 200°C morphologically, which increased in number and length with rising temperatures. Disjunction of enamel and dentin occurred at 400°C in incisors and at 600°C in molars. Using scanning electron microscopy studies, Muller *et al*. demonstrated cracks at 150°C which further increased with higher temperatures.[11] This was similar to the findings in our study. Enamel and dentin have different coefficients of thermal expansion, and hence, the crowns tend to fracture at dentinoenamel junction. Reticular cracks were appreciated on the root surface from 600°C onward. The roots remained intact even at 800°C. Thus, in high thermal hazards, root remains are of utmost forensic value in the identification of the victim or individual.

Radiographic alterations of teeth

Radiographic alterations are shown in Figure 2. Radiographs showed coronal dentin cracks at 400°C. Radicular dentin remained relatively intact at 400°C possibly due to intact cementum. At 600°C, radiographs showed radicular dentin cracks.

Table 4: Differences observed in the radiographic appearance of the restorations at various temperatures

Temperature (°C)	Amalgam	Composite	Glass ionomer cement	Endodontic restoration
200	No changes in shape and dimensions	No changes in shape and dimensions	No changes in shape and dimensions	Radiopacity less regular, presence of radiolucent area, shape and dimension slightly altered
400	No changes in shape and dimensions	No changes in shape and dimensions	No changes in shape and dimensions	Radiopacity less regular, presence of many radiolucent areas, "honeycomb" appearance, shape and dimension slightly altered
600	No changes in shape and dimensions (even in samples with detachment of crown and restorations)	No changes in shape and dimensions (even in samples with detachment of crown and restorations)	No changes in shape and dimensions (even in samples with detachment of crown and restorations)	Radiopacity less regular, presence of many radiolucent areas, "honeycomb" appearance, shape and dimension slightly altered
800	Large radiolucent fissures between dental tissue and restorations - no changes in shape and dimension (even in samples with detachment of crown and restorations)	No changes in shape and dimension (even in samples with detachment of crown and restorations)	No changes in shape and dimensions (even in samples with detachment of crown and restorations)	Radiopacity less regular, presence of many radiolucent areas. "Honeycomb" appearance, shape and dimension slightly altered

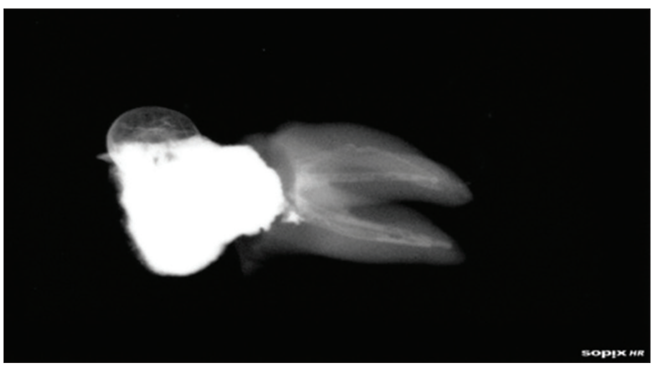


Figure 3: Change in shape of amalgam at 800°C

Heat-induced stress causes cracks and fractures in a tooth, based on the temperature difference between the tooth and the environment and rate of heat transfer. Hence, if a heat-treated tooth is examined before it attains room temperature, the number of visible cracks may be minimal, which the forensic dental expert should take into consideration. Furthermore, slower the rate of heat transfer, the lesser the number of cracks seen.

Effect of heat on restorations

All restorations remained intact without change in the shape till 800°C. Glass ionomer, amalgam, and composite restorations showed no adaptation to cavity surfaces at 600°C suggesting the shrinkage of restorative materials. At 800°C, there was change in the shape of amalgam restoration of one tooth [Figure 3]. According to Rossouw *et al*., restorative materials such as GIC and composites are heat resistant.[12] They become more fragile and need careful handling during collection of samples of remains and their examination. Radiographically, there was no appreciable change in density of restorations except gutta-percha which appeared comparatively less radiodense with reticulated pattern at

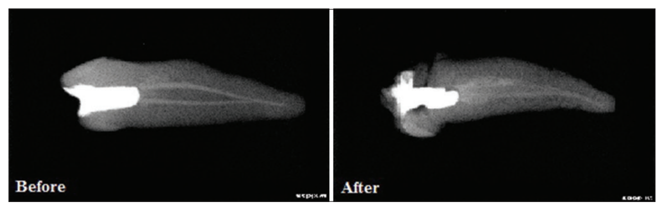


Figure 4: Filling of unfilled root canal at 600°C

600°C. It flowed out through apical foramen at 400°C. At 600°C, the endodontic material had flown into the accidentally unfilled canals in one tooth [Figure 4]. Similar finding was reported by Savio *et al*.[6]

Conclusion

Thus, the study within its limits brings forth the changes taking place in the teeth and restorations that could aid examiners during forensic investigation of incinerated victims.

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Conflicts of interest

There are no conflicts of interest.

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