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Effects of elevated temperatures on different restorative materials: An aid to forensic identification processes

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Abstract

Background: Heat-induced alterations to dental and restorative materials can be of great interest to forensic dentistry. Knowing the specific optical behavior of dental materials can be of high importance as recognition of changes induced by high temperatures can lead to the determination of material which was used in a dental restoration, facilitating identification of burned human remains. **Aim:** To observe the effects of predetermined temperatures (200°C–400°C–600°C–800°C–1000°C) on unrestored teeth and different restorative materials macroscopically and then examine them under a stereomicroscope for the purpose of identification. **Materials and Methods:** The study was conducted on 375 extracted teeth which were divided into five groups of 75 teeth each as follows: group 1- unrestored teeth, group 2- teeth restored with all-ceramic crowns, Group 3- with class I silver amalgam filling, group 4- with class I composite restoration, and group 5- with class I glass ionomer cement restoration. **Results:** Unrestored and restored teeth display a series of specific macroscopic & stereomicroscopic structural changes for each range of temperature. **Conclusion:** Dental tissues and restorative materials undergo a series of changes which correlate well with the various temperatures to which they were exposed. These changes are a consequence of the nature of the materials and their physicochemical characteristics.

Key words: Forensic identification, restorative materials, stereomicroscope, temperatures

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Introduction

Human identification is one of the major fields of study in forensic science.[1] Identification of unknown individuals is of paramount importance in medico-legal cases to resolve criminal investigations, insurance settlements, for proper burial, and for grief resolution of family and friends.[2]

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Identification of human remains in mass disasters is a difficult task. 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 particularly resistant composition and protection by soft tissues.[3]

Restorative materials like gold, silver amalgam, and porcelain are often unaffected even after prolonged exposure to fire. This specific characteristic creates a gold standard for victim identification and can be applied even in cases when only a single tooth exists.[4]

The combination 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.[5]

Most features of damage to the oral tissues and dental restorations can be observed directly by the naked eye, but additional microscopic investigations can be very useful in studying the finer details of the dental tissues, the surfaces involved in dental treatment, and any distinguishing traits in the restorative materials present. The same is true for prosthetic devices.[6] Therefore, the changes observed in the specimens allow a reasonably reliable estimate of the temperatures to which they have been exposed and the characteristics of the original state prior to heating.

The purpose of this study was to observe the macroscopic and stereomicroscopic (SM) changes taking place on unrestored teeth and various commonly used restorative materials like ceramic crowns, silver amalgam, composite, and glass ionomer at predetermined temperatures of 200°C–400°C–600°C–800°C–1000°C.

Materials and Methods

In the present study, 375 extracted teeth, disinfected in a 5% sodium hypochlorite solution for 1 h, were divided into five groups as follows:

Group 1: 75 teeth which were free from any pathology

Group 2: 75 teeth which were restored deliberately for the experiment with all-ceramic fixed crown prosthesis (Ceramco II material; Dentsply International Inc., New York, United States)

Group 3: 75 teeth with class I silver amalgam filling (DPI alloy fine grain; Bombay Burmah Trading Corporation Ltd., Mumbai, India)

Group 4: 75 teeth with class I composite restoration (Esthet •X HD; Dentsply International Inc., New York, United States)

Group 5: 75 teeth with class I glass ionomer cement (GIC) restoration (GC Gold Label Glass Ionomer Universal Restorative; Liuzhou Shengji Medical Apparatus Co. Ltd., Liuzhou, China).

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

To avoid experimental or measurement bias, restorative materials 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 using "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 were done.

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

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 tooth sample was examined macroscopically and then under a stereomicroscope (Zeiss Stemi DV4 Stereo Zoom Microscope) at 15 × magnification.

Results

The effects of varying temperatures on the unrestored and restored teeth were observed mainly in the form of color changes, cracks, fragmentation, and marginal seal of restorative materials. At the specified temperatures, all samples of each group showed similar observations [Figures 1 and 2].

Macroscopic analysis of color changes of unrestored and restored teeth are presented in Table 1.

Unrestored and restored teeth showed different color change characteristics for each range of temperature.

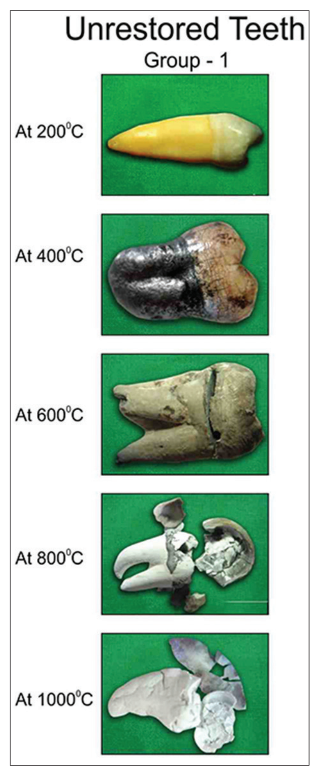

Figure 1: Effects of different temperatures on unrestored teeth (group 1- unrestored teeth)

SM analysis of cracks and fragmentation of unrestored and restored teeth is given in Table 2.

At 200°C, unrestored teeth did not show any signs of fracture. As the temperature increased, the crown had fragmented into pieces whereas the root remained intact.

Ceramic crowns did not show any cracks and fragmentation even at 1000°C.

Composite material showed cracks at lower temperatures (400°C) as compared to amalgam (800°C), and both the materials showed fragmentation at 1000°C.

GIC restoration cracked at a low temperature of 200°C and fragmented at 800°C. Except GIC, the other three restorative materials could withstand temperatures of 200°C.

SM analysis of marginal seal of restorations is given in Table 3.

At 200°C, ceramic crowns, amalgam, and composite material showed unchanged marginal seal, whereas GIC fillings slightly extruded from cavity margins.

At 400°C, all restorative materials except ceramic crowns showed a marginal contraction.

At 800°C, ceramic crowns appeared to have detached from the cervical region.

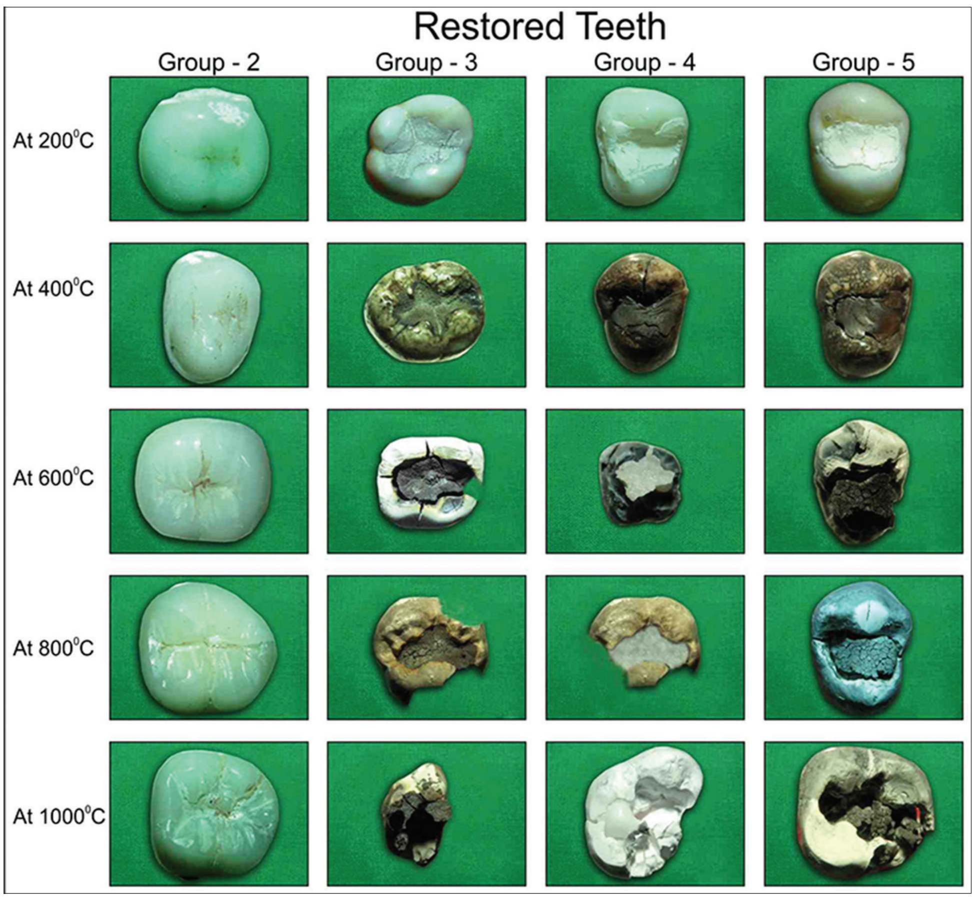

Figure 2: Effects of different temperatures on restored teeth (group 2- all-ceramic crowns, group 3- silver amalgam, group 4- composite restoration, group 5- glass ionomer cement)

Table 1: Macroscopic analysis of color changes of unrestored and restored teeth

Temperatures	Unrestored teeth		Restored teeth			
	Crown	Root	All-ceramic	Amalgam	Composite	GIC
200°C	Yellow to light brown	No change	No change in color	Loss of luster	No change in color	Chalky white
400°C	Gray to brown	Shiny black	Fine black spots seen	Opaque black	Black	Dark brown
600°C	Gray color enamel and dentin	Brown	Dull and darker	Opaque black	Chalky white	Black
800°C	Grayish brown	Chalky white	Dull and darker	Opaque black	Chalky white	Black
1000°C	Grayish white	Pinkish white	Dull and darker	Opaque black	Chalky white	Black

GIC: Glass ionomer cement

Table 2: SM analysis of cracks and fragmentation of unrestored and restored teeth

Temperatures	Healthy teeth	All ceramic	Amalgam	Composite	GIC
200°C	No cracks	No cracks	No cracks	No cracks	Cracks
400°C	Cracks on crown and root	No cracks	No cracks	Cracks	Cracks
600°C	Cracks on crown and root	No cracks	No cracks	Cracks	Cracks
800°C	Fragmentation of crown and cracks on root	No cracks	Cracks	Cracks	Fragmentation of restoration
1000°C	Fragmentation of crown completely and cracks on root more marked	No cracks	Fragmentation of restoration	Fragmentation of restoration	Fragmentation of restoration

SM: Stereomicroscopic, GIC: Glass ionomer cement

Table 3: SM analysis of marginal seal of restorations

Temperature	Ceramic crowns	Amalgam	Composite	GIC
200°C	Unchanged marginal seal	Unchanged marginal seal	Unchanged marginal seal	Slightly extruded from cavity margins
400°C	Unchanged marginal seal	Marginal contraction	Marginal contraction	Marginal contraction
600°C	Unchanged marginal seal	Marginal contraction	Marginal contraction	Increased marginal contraction
800°C	Detached from cervical margin; showing no contraction/fragmentation of crown	Increased marginal contraction	Increased marginal contraction	Fragmentation of restoration
1000°C	Detached from cervical margin; showing no contraction/fragmentation of crown	Fragmentation of restoration	Fragmentation of restoration	Fragmentation of restoration

SML: Stereomicroscopic GIC: Glass ionomer cement

At 1000°C, all the restorative materials except ceramic crowns showed fragmentation.

Discussion

In forensic odontology, a great deal of effort goes into identifying the victim. One method of identification in forensic odontology 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.[7]

One of the first studies on identification of human remains by dental examination goes back to 1897 and was carried out following the fire at the Bazar de la Charite, France.[8]

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°C and 982°C[9] and combustion of petrol occurs between 1600°F and 1800°F (8000–1100°C).[6] The temperature reached in many fire accidents 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 which may have a considerable effect on the tooth and its restorations.[6]

Thus, in this study, the teeth were subjected to five different predetermined temperatures of 200°C, 400°C, 600°C, 800°C, and 1000°C, simulating temperatures in various fire accidents.

Among the changes in behavior of the tissues and restorations observed, change of color was the most common finding, characteristic for each range of temperature, and this was directly related with the level of carbonization and incineration of teeth. These findings were in accordance with those of Delattre[1] and Merlati *et al*.[6]

Besides direct visual inspection of dental remains, SM examination gives better details of tooth changes and a clear picture in the identification of the charred dental material remnants, which would otherwise go unnoticed in the huge fire debris, particularly when only fragments of the teeth remain available for analysis.[10]

According to the Gustafson, no major changes are observed in unrestored and restored teeth below 200°C. Hence, the study commenced at a temperature of 200°C and above. At 200°C, the teeth did not show any signs of fracture. As the temperature increased, cracks were seen in crown and root at 400°C and fragmentation of crown was observed at 800°C. At 1000°C, the root remained intact despite the crown being shattered into pieces. Thus, root was found to be more resistant as compared to crown. This was in accordance with the report by Merlati *et al*.,[6] which highlighted the important point that calcinated teeth, being completely dehydrated, are very delicate.

All-ceramic crowns are being increasingly used worldwide. No data exists about the effects of high temperature on this material. Our findings showed that ceramic crowns did not show cracks and fragmentation at temperatures as high as 1000°C. Ceramic crown showed highest resistance to fire with no cracks and unchanged morphology, possibly due to its composition and mechanical properties of low thermal conductivity, high hardness, and chemical inertness.[11] As the ceramic restorations could still be identified at high temperatures, it is a boon to restorative as well as forensic dentistry.

GIC restoration cracked at a low temperature of 200°C and fragmented at 800°C. Between amalgam and composite, composite material showed cracks at lower temperatures (400°C) as compared to amalgam (800°C) and both the materials showed fragmentation at 1000°C. Thus, amalgam was found to be more resistant than GIC and composite. The most resistant of all the materials tested was all-ceramic, which did not crack until 1000°C, and GIC was the least resistant to fire.

The present study also showed restored teeth having cracks and crown shattering at lower temperatures compared with unrestored teeth. This may be the result of alterations in structural integrity of the hard tissue due to cavity preparation, which may have resulted in its early damage. This was in accordance with the results of other similar studies that were performed.[6]

At 400°C, amalgam, composite, and GIC fillings showed a marginal contraction probably due to the evaporation of the mercury and loss of the organic matrix.[12] Hence, it is possible to write down that at 400°C, all the restorative materials except ceramic crowns showed a marginal contraction. Ceramic crowns appeared to have detached from the cervical region at 800°C. At 1000°C, all the restorative materials except ceramic crowns showed fragmentation.

The color, cracks, fragmentation, and marginal seal scale obtained in our study for each temperature offer a practical comparative method for use in forensic investigations. Thus, bodies exposed to high temperatures can be subjected to microscopic analytical methods.

Thus, when there is severe damage to teeth and associated structures as a result of fire, along with conventional means of dental identification, evidence may be salvageable through the use of stereomicroscope.

Conclusion

Our results indicate that unrestored and restored teeth will provide a source of forensic evidence after exposure to temperature of up to 1000°C, indicating that this information can be used as a means of comparison in human identification of victims in fire accidents.

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