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"The Burning Tooth" A Radiographic and Microscopic Study to Aid Identification Process in Fire Disasters

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ABSTRACT
A major obstacle in the forensic investigative process after large-scale disasters is the use of dental tissues for identification, especially following exposure to fire. The recovery of evidence and identification of the cremated victims both heavily rely on forensic dentistry. This "in vitro" study's objective was to evaluate the microscopic and radiographic characteristics of unrestored and restored teeth following exposure to a controlled range of high temperatures. Three groups of fifty human teeth were created: (1) unrestored teeth, as a control group, (2) teeth restored with amalgam, glass ionomer cement (GIC) and composites and (3) a group consisting of teeth restored with crown and bridges specifically for this study. The periapical radiographs and microscopic examination of all the specimens before and after exposing the teeth to high temperatures were carried out. The studies involving heat exposure were conducted in a burnt-out furnace at temperatures between 250º and 1150º C. All of the teeth's radiographs and microphotographs were analyzed both before and after the thermal stressors, with the discrepancies noted. The tooth structure can sustain some little damage in the majority of fire disasters. When good ante mortem records are available, the relevance of such a tooth can be of interest in identifying people because it can tolerate greater temperatures when all other tissues might not live to be recognized. The kind of filling, restorative materials used, as well as the shape and form of the prosthesis, may add to the supporting evidence in this process.
KEYWORDS: *Forensic dentistry; Radiographs; Microscopy; Fire disasters*

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INTRODUCTION

When it comes to man-made or natural disasters that cause fatalities but may not leave behind fingerprints, forensic odontology plays a significant part in the identification process. One of the biggest issues in a major disaster is the accurate identification of victims. In some nations, sight recognition may be the only standard for victim identification [1].
However, the outcomes of such a non-scientific method frequently produce unreliable results. As a result, it is more dependable to rely on other factors in addition to visual recognition in order to assure a more certain identification. Physical evidence gathered from the body should serve as the main source of information when identifying an unidentified body. A precise identification is made by comparing ante mortem (AM) and postmortem (PM) data with physical evidence from an exterior examination and circumstantial evidence (such as clothing, jewellery, and pocket contents). Finding and identifying evidence like bullets or bomb fragments can be done extremely successfully using X-ray examination [2].
Aside from techniques like fingerprinting and DNA profiling, dental comparisons are among the most accurate ways to identify someone [3]. The human body's hardest tissue is its teeth, which are resistant to a variety of external factors as well as mechanical, thermal, and chemical irritations. In mass casualty disasters, dental radiography serves as a vital tool for reliable identity verification and individual identification. The radiographic comparison, as opposed to one in pictures, takes use of the matching of similar features at two levels of anatomical complexity: exterior shape and interior architecture [3, 4].
Teeth are among the components that frequently withstand intense fires due to their make-up and anatomical placement. According to the temperature achieved, the environment (open or closed), the type of oxidants present, the length of the combustion process, and the effects of the various fire-extinguishing agents employed, they demonstrate the damage inflicted by fire. Such damage may make it

more difficult to identify fire victims. In fact, it frequently occurs that the study may only be able to be performed on tooth pieces [4].
The present study was planned to evaluate the damages to the teeth at different grades of temperature, so that the correlating possibility of teeth may help in the identification process of victims in different kinds of fire disasters.
In this work, we heated the teeth to a variety of temperatures that are typical of fire disasters, such as house fires (250°C to 700°C), bomb blasts (400°C to 7000°C), air crashes (1000°C to 1700°C), and automobile accidents. In this work, the behaviour of teeth exposed to various temperature ranges and an examination of structural variation are reported. The following report includes a number of insightful remarks that might aid in the identifying process.

MATERIAL AND METHODS

For the study, fifty healthy human teeth that had been extracted for orthodontic purposes were disinfected for one hour in a 5% sodium hypochlorite solution and kept at room temperature in formalin solution.(Fig. 1).
The study group was divided into three groups. (1) Normal unrestored teeth (n= 10), (2) teeth restored with silver amalgam, composite and GIC type II (n= 10 in each subgroup) and (3) teeth restored with crown and bridge (n=10). All the cavity and tooth preparations were performed as per the guidelines in the phantom head laboratory and strict clinical protocols were observed in the fabrication and insertion of restoration.

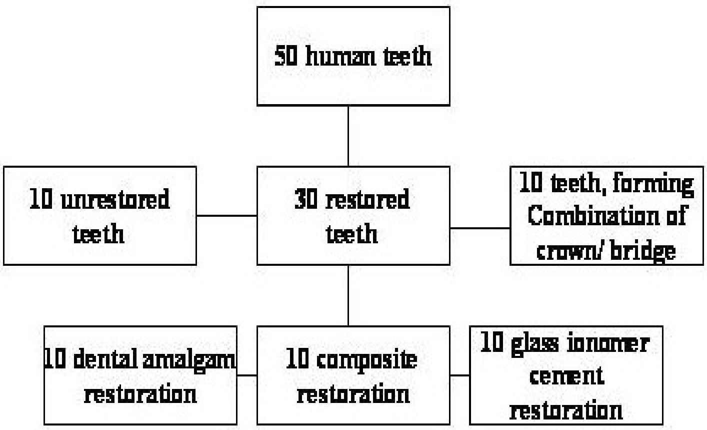

Figure 1, Flow chart which shows the composition of the experimental group.

After the restorations were placed, all the teeth were stored in 10% formalin solution at room temperature prior to the procedure. Then, the periapical radiographs and photomicrographs of all the samples were recorded. Photomicrographs were taken with Macro dual zoom connected to Reichert Jung Polyvar 2 microscope via dual reflex module at a magnification of 4x.
Out of the above mentioned samples, five sets were made with 10 teeth each. Each set contained 2 unrestored, 6 restored teeth and one crown/bridge unit (fig. 2).

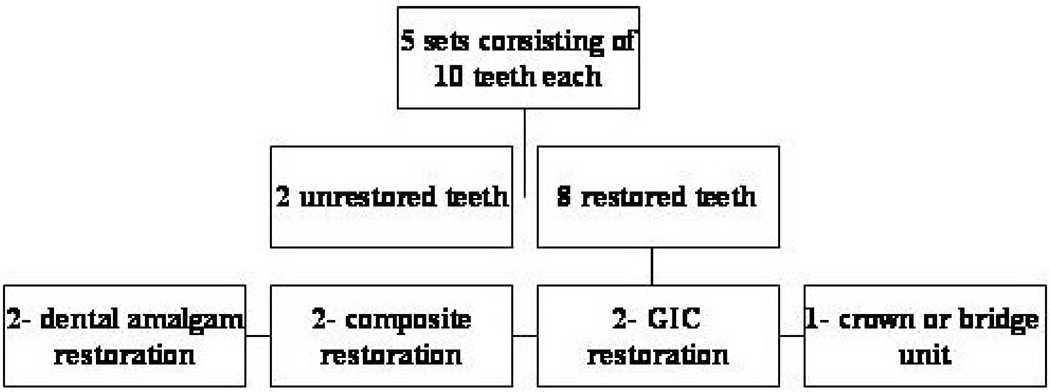

Figure 2, Flow chart which shows the composition of each set of samples

Each set, out of the samples made, they were exposed to the heat in a burn out furnace (Bego, Miditherm Furnace, Germany) at five different temperatures. 4 sets were subjected to a preheated furnace with temperatures of 250, 550, 850 and 1150^0C and the last set was exposed to a gradual rise in temperature from 250 to 1150^0 C with an increment of 9^0 C/minute.
Each set was held in the oven for twenty minutes after the target heat was reached, after which it was removed and left to cool to room temperature. When the oven displayed a temperature of 2500 C, the fifth set of teeth was held there until it displayed a temperature of 11500 C. After that, it was removed from the oven. The sets of samples had to be taken out of the oven for around 10 seconds.
The teeth were radiographed and microphotographed following each session of heat exposure. Two dentists worked together to evaluate the image qualities of the ante mortem and postmortem radiographs and microphotographs, taking into account the shape, size, and relationships between radiopacity and radiolucency of the structures involved. The ensuing variations among the samples exposed to different temperatures were noted and examined.

RESULTS

Tables 1 and 2 present the findings of the radiographic and microscopic study and detail the differences between the samples and the remains as seen on radiographs and under the microscope.

Table 1, Microscopic and Radiographic observations in unrestored teeth when exposed to experimental ranges of temperatures

Temperatures (in degree C)	Microscopic observations	Radiographic observations
250 (direct exposure)	No changes in crown Cementum lost from root**(fig 3)**	No changes in crown ***Cementum loss not appreciable***
550 (direct exposure)	Crown appears burnt off with loss of enamel Root- burnt off, chalky appearance	Fissure between enamel & dentin, with crown destruction ***Root- changes not seen*** **(fig 4)**
850 (direct exposure)	Enamel tearing off, chalky Crown fracture & detachment Root- dentine tearing off ***Root changes better appreciated***	Fractures between enamel/ dentin, crown detachment Root- fissures/ cracks within dentin **(fig 5)**
1150 (direct exposure)	Fractured crown, reduced in size and shape, Root- large cracks & chalky, brittle surface **(fig 6)**	Large fracture lines through crown Root- numerous fracture lines seen, but still maintaining the shape
250- 1150 (gradual rise)	Tooth broken down in fragments Whitish chalky shattered appearance	Crown reduced in fragments Roots broken down in half *Tooth appears more damaged***(fig 7)**

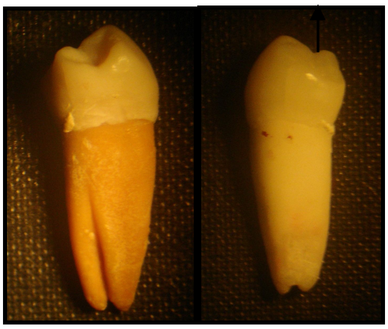

Fig 3

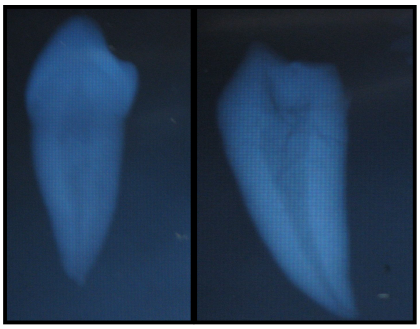

Fig 4

Fig 5

Fig. 3, showing loss of cementum in tooth after an exposure at 250^o c
Fig. 4, showing fracture line development along with crown damages at 550^o c
Fig. 5, showing fracture lines in dentin along with crown detachment at 850^o c

 

Fig.6 Showing crown, reduced in size and shape, & chalky, brittle, cracked root surface at direct exposure of 1150^0 C

Fig.7 Crown reduced in fragments Roots broken down in half at gradual rise of temp from 250 to 1150^0 C

Table 2, Microscopic and Radiographic observations in restored teeth when exposed to experimental ranges of temperatures

Temp In $^\circ$ C	**Appearance**	**Dental amalgam**	**GIC**	**Composite**	**Crown & Bridges**
250, direct exposure	Radiologic	No changes	No changes	slight development of crack evident at tooth- restoration interface **(Fig. 8)**	No changes
	Microscopic	No changes	Development of fine crack within restoration. **(Fig. 9)**	Slight separation evident	No changes
550, direct exposure	Radiologic	Large fissures between dental tissue and fillings— One tooth showed the restoration detachment	Restoration intact except for development of fine cracks evident both radiologically & microscopically	Total detachment of restoration , with no evidence of it	Restoration partially detached from crown along with leutting agent(GIC1), restoration intact
	Microscopic	Cracks seen at tooth restoration interface.		Restoration burnt off except for fine particles still adhering to tooth	-do- **(Fig. 10)**
850, direct exposure	Radiologic	Detachment of restoration from crown, restoration still in shape, (even in samples with detachment of crown and fillings). **(Fig. 11)**	No traces of restoration seen, a line of fracture in radicular dentin seen below cavity area	Crown detached from root, no particles of restoration seen in burnt remains as well	Restoration intact, totally detached from tooth along with a cap of enamel, dentin and peeling off of the tooth structure.
	Microscopic	Burnt off appearance of restoration along with Detachment of restoration from crown	Restoration burnt off totally, detached from tooth surface, creation of void at place of restoration. **(Fig. 12)**	No evidence of restoration, crown shattered	-do-
1150, direct exposure	Radiologic	Restoration fragmented, Crowns reduced in fragment	Crowns reduced in fragments, restoration not appreciable	Tooth shattered in fragments, no evidence of restoration	Ceramic fracture could not be appreciated
	Microscopic	Crown shattered, restoration cracked and mixed among remains	-do-	-do-	Restoration intact, tooth totally shattered, ceramic part got fractured.
250-1150, gradual rise	Radiologic	Restoration fragmented, separated from crown. Crowns reduced in fragment	Crowns reduced in fragments, restoration not appreciable	Tooth shattered in fragments, restoration not appreciable	Restoration intact, tooth totally shattered **(Fig. 13)**
	Microscopic	Restoration detached & shattered in fine particles	-do-	-do-	Ceramic lost from metallic crowns

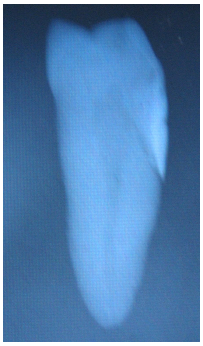


Fig. 8 : Initial development of crack evident at tooth- restoration interface at an exposure of 250 ^{0} C
Fig 9: Development of fine crack within GIC restoration, at an exposure of 250 ^{0}C
Fig. 10 : Crown & bridge restoration partially detached from crown along with leuting agent remained (GIC-1), restoration intact at an exposure

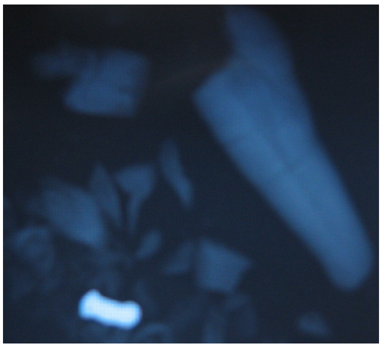


Fig.11 Detachment of dental amalgam restoration from crown, restoration still in shape, at an exposure of 850 ^{0} C
Fig.12 GIC restoration burnt off totally, detached from tooth surface, creation of void at place of restoration at an exposure of 850^0 C


Fig13: Crown & bridge restoration intact, tooth totally shattered, ceramic part got fractured evident in figure at right side at an exposure of gradual rise of temp from 250 to 1150^0 C

DISCUSSION

The identification of the bodies of numerous leaders who were assassinated, like Zian ul Haq, Adolf Hitler in the public eye, Rajeev Gandhi, etc., relied heavily on their dental health. When it comes to man-made or natural disasters that cause fatalities but may not leave behind fingerprints, forensic odontology plays a significant part in the identification process. The majority of insults and repercussions endured during death and during decomposition are not harmful to teeth (explosions, accidental trauma, aircraft crashes etc).

Once the predetermined temperatures were attained in the current investigation, samples were immediately withdrawn from the furnace and allowed to cool to room temperature. As a result, each specimen only experienced one thermal shock rather than several. The time of exposure to the fire, how it developed, how quickly the temperature increased, and the materials used to put out the fire are only a few of the variables that could affect the remains that were recovered "in vivo." Some factors that might be present "in vivo" circumstances, such as the protection provided by soft and hard tissues surrounding tooth parts, were not taken into account in our research. Such "in vivo" variables prevent teeth from

being exposed to heat directly. We did our best to replicate the same conditions that might be present in different fire disasters within the constraints of our "in vitro" investigation.
With the exception of the loss of cementum shown in microphotographs of nearly all the samples, no changes were noted by radiographic examination at 250 0C between the unrestored and restored teeth. [Fig. 14].

Fig. 14 : Showing unaffected appearance of amalgam restoration at a temperature of 250^0 C

Among restored teeth, development of a mild crack in GIC restoration was evident microscopically and a slight degree of separation was seen in composite restoration radiographically. These findings are particularly important in identification of incinerated victims of small fire disasters such as accidental house fires. Our second set of sample was subjected to a temperature of 550^0 C as one can encounter such temperature in peripheral sites of bomb explosions, large scale house fire [6]. After exposure to 550^0 C, all the teeth showed slight destruction of crown with no further damages to root. Radiographic evaluation pointed out cracks and fissures in teeth and microscopic examination revealed burnt off chalky appearance of root with enamel and dentin peeling off the tooth surface. In restored teeth, amalgam fillings showed crack between dental tissue and fillings, while one restoration got separated from the tooth totally and the crown got shattered GIC restoration showed development of fine cracks evident microscopically while composite restorations got totally separated from the teeth (Fig. 15).

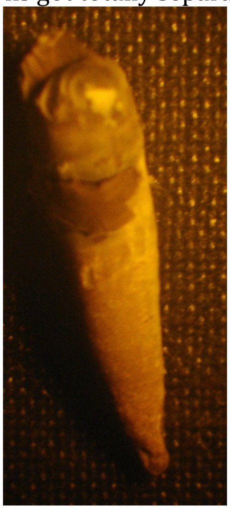

Fig. 15: Showing burnt off, intact appearance of GIC restoration at a temperature of 550^0 C

Crown and bridge restorations showed a partial detachment of restoration along the leuting media (GIC type I cement) and tooth interface. This may be because of lesser strength and ability of GIC type-I restoration to withstand such temperatures.
After an exposure of samples at a temperature of 850^0 C, which can be rapidly reached in core sites of bomb explosions and inside cabins of crashed air crafts teeth showed the detachment of the crown which fractured soon thereafter because of too much brittleness. Microscopic examination showed chalky, cracked radicular portions along with flecks of dentin tearing off the root surface. Correspondingly, radiographs showed development of large fractures and crack lines in entire teeth [6, 7].
At 850^{0}C, all the restorations got totally separated from the teeth, with amalgam restoration still maintaining its shape in detached crown. GIC restoration got totally burnt off leaving a void at the cavity

area. Teeth restored with composite showed fractures in the crown as well as root. Though crown and bridge restorations got totally separated from the teeth pulling apart fractured enamel and dentin, still they were intact.
Furthermore, fire mass disasters can raise temperatures up from 1000⁰ C to a whopping temperature of upto 7000⁰ C such as in big industrial fires, forest fires, powerful bomb explosions, air crashes and vehicular accidents etc[6]. Within limits of facilities available with us; we could expose the samples up to a temperature of 1200⁰ C only. The experimental groups were subjected to sudden predesignated temperatures to know the effect of such temperatures on the tooth and the group which was exposed to the gradual increase in temperature (250 to 1150⁰C) may simulate victims trapped inside an inferno for longer durations.
All of the teeth displayed crown detachment after being exposed to a direct heat of 11500 C, and the crowns were reduced to little fragments. As seen on radiography and microphotographs, roots were also broken. When the teeth were exposed to a gradual temperature increase from 2500 C to 11500 C, similar outcomes were achieved. But there was more distortion across the entire clip. (Fig. 16).

Fig. 16: Showing shattered, detached & fragmented tooth at a gradual rise of temperature from 250⁰ C to 1150⁰ C

After exposing restored teeth to a temperature of 1150⁰C all teeth got shattered, fractured with no evidence of GIC and composite restoration particles evident radiographically or microscopically. Amalgam particles could still be identified in the burnt remains radiographically. Crown and bridges showed development of fine cracks in porcelain fused to metal restoration and were still very much intact. Similar results were obtained in a direct heating of all restoration from 250⁰ C to 1150⁰ C.
From this study, we observed that a tooth is one of the most important structures to look out for in forensic investigations of incinerated victims of fire disasters. Most of the fire disasters can do a little damage to the tooth structure.
If accurate ante mortem records are available and teeth are able to endure greater temperatures when all other tissues would not, the relevance of such teeth can be of interest in identifying people.
The type of filling, restorative materials, design and form of prosthesis may add to the corroborative evidence in this process. If even, fragments of shattered tooth can be recovered from burnt ashes in mass fire disasters, they can be helpful in obtaining DNA from entrapped cells such as cementocytes through cryogenic grinding, which may be an important lead in identification process [2].

CONCLUSION

Within the confines of our study, we demonstrated how our observations sparked some stimulating conversations that aided in the recognition procedures. In order to simulate settings that are closer to reality, we will focus on enhancing our experimental approaches.

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