HEAT IMPACT ON TEETH: A FORENSIC STUDY

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ABSTRACT:

Aim: The aim of this experimental in vitro study was to evaluate the morphologic and radiographic features of teeth after exposure to an experimental range of high temperatures and to assess the degree of destruction in colour, and crazing of samples.

Materials and Methods: the study was conducted to observe macroscopic and radiographic changes in the human teeth the teeth were grouped based on temperature range (200^{o} C 400 ^{o}C 600 ^{o} C and 800 ^{o} C to which its exposed during incineration.

Results: Various changes in relation to temperature were observed macroscopically and radio graphically.

Conclusion: The study was carried out to study the gross changes both macroscopically and radio graphically in human teeth exposed to various temperature ranges.

Keywords : crazing of samples, incineration, human teeth.

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WHOLE PAPER:

INTRODUCTION

Human identification is one of the major fields of study in forensic science because it deals with the human body and aims at establishing human identity. Dental identification is one of the most reliable and frequently applied methods of identification, and forensic odontology is a speciality in itself. The establishment of forensic odontology is a 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.[1]

Forensic odontology plays a significant role in identification of individuals in case of crime investigations or during autopsy. Forensic odontology becomes even more important when bodies are decomposed, skeletonized, or mutilated. This is because dental hard tissues have some morphological characteristics, and perhaps restorations, anomalies, or pathologies, that make them as specific as a fingerprint. Teeth are the hardest structures of the human body, thus they are highly resistant to cadaveric decomposition and long burial periods, and teeth can also survive the action of temperatures as high as 1100°C; for these reasons the dental hard tissue examination can help solve some mysteries.[2]

Being hardest components in the body that often survive severe fires because of their high resistant composition and also because they are protected by the soft and hard tissues of the face and other elements.[3]

Recently, focus of analysis has shifted from macroscopic heat-induced changes to microscopic changes. In general, macroscopic changes can be influenced by a large number of external factors such as time and temperature of heat exposure, availability of oxygen, as well as material properties; and therefore do not seem to be the ideal tool for temperature estimation. All of these sophisticated but destructive methods have been used throughout many decades, and can be useful for the estimation of cremation temperature range of bones and teeth.[4]

Changes in the color of burnt teeth can provide information on their fragility and recovery, trauma history, structural changes, and on the temperature to which they were exposed.[5]

Though fire has become the most useful agent, yet it has proved to be one of the most destructive enemies of man. Fire destroys property, wipes out thousands of lives every year and thereby cause wastage of human resources. Burn injuries are caused due to contact with dry heat. Burn is an injury which is produced by the application of dry heat such as flames, radiant heat or heated substance over the body service. The term burn is restricted to the local effects of dry heat. By law all dry heat lesions have been designated as burns. Burn injuries have long been described as among the most serious injuries that may afflict a human being.[6]

In some cases fire is used to destroy forensic evidence and prevent clear identification and recovery. Hence Positive identification and investigation of burned human remains require a great deal of experience and care. Hence Forensic odontology in particular has been seen to be useful when the damage has been caused by heat.[1]

Materials and Method:

A total of 75 freshly extracted unrestored permanent teeth fixed in 10% formalin, were randomly collected from clinics in Kanpur city, the reason for extraction was orthodontic and periodontal purposes. Following extraction each tooth was rinsed with saline water to remove blood deposits and salivary coating.

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The teeth were stored in 10% formalin for 15 days, after which they were removed. Formalin (10% concentration) was used as the storage medium for the teeth because it is known to have a minimal effect on permeability, in comparison with other storage media such as 70% ethanol and distilled water. Samples excluded from the study were damaged or fractured teeth. Endodonticaly treated teeth, teeth with dental restorations or caries.

The teeth used for the study were rinsed thoroughly in tap water and cleaned with a tooth brush in order to remove any deposits.

Each group of teeth was exposed to temperature range 200^{o} C 400 ^{o}C 600 ^{o} C and 800 ^{o} C in the furnace.

Once placed in the furnace, the teeth were incinerated for a period of 10 minutes; the teeth were then removed and allowed to cool to room temperature in air and then stored in square box padded with cotton. Post exposure photographs were taken to maintain records.

Post exposure radiographs was taken to record the changes.

Results:

Macroscopic changes-

Teeth samples at 200^{0}c when observed with naked eye under sufficient sunlight showed crown with greyish to brownish in colour with minute chip of enamel portion, dentin shows greyish to blackish in colour, 1/3rd of the crown was destroyed. Root shows greyish to brownish in colour with horizontal cracks visible around the CEJ. Under stereomicroscope the teeth samples at 200^{0}c showed creamish to brownish in colour with minimum minute cracks present on the surface of the samples. The occlusal radiographs showed increase in distance between DEJ caused due to cracking and increased opacity of crown.

Teeth samples after incineration at 400^0c the crown showed greyish to blackish in colour, crack is seen near CEJ with chipped of enamel, and vertical crack is seen in root from CEJ towards bifurcation of the root. Root shows chalky white appearance. Under stereo-microscope the enamel of crown showed blackish grey to whitish colour change. At the areas where the enamel was chipped off and dentin was exposed, dentin was greyish in colour and cementum was whitish, enamel was separated with DEJ. The occlusal radiographs showed increase in distance between DEJ & CEJ (moderate) due to cause of crack in the crown portion at the crown to root junction level.

Teeth samples at 600^0c post incineration dark grey or blackish in colour of crown followed by detachment of crown from the root and torn into pieces was seen. The stereo-microscope showed brownish to blackish greasy shine in colour of teeth samples exposed at 600^0c, enamel chipped off, dentin blackish in colour was observed. Under occlusal radiographs of teeth samples post incinerated at 600^0c showed fracture of teeth at DEJ.

Teeth samples incinerated at 800^0c showed multiple fractures and samples torn into pieces when observed under naked eyes. But under stereo-microscope the teeth samples incinerated at 800^0c showed cracks extending from CEJ towards the root, colour was greyish silvery. The occlusal radiographs of teeth samples incinerated at 800^0c were severely damaged tooth torn into small pieces and fracture of tooth at CEJ.

Fig. 1 Creamish to brownish in colour with minimum minute cracks present on the surface of the samples with chipped of enamel at 200^{0}c.

Fig. 2 : Crown greyish, root whitish enamel is looking blackish grey, dentin is greyish, cementum is whitish, enamel is got separated with DEJ at 400^{0}c

Fig. 3 :Brownish to blackish in colour enamel is chipped of, dentin is blackish in gross appearance at 600^0c

Fig. 4 : Cracks can be seen from CEJ towards the root silvery grey in colour at 800^0c

Radiographical changes observed-

Teeth samples at 200^0c when observed with naked eye under sufficient sunlight showed crown with greyish to brownish in colour with minute chip of enamel portion, dentin shows greyish to blackish in colour, 1/3rd of the crown was destroyed. Root shows greyish to brownish in colour with horizontal cracks visible around the CEJ. Under stereomicroscope the teeth samples at 200^0c showed creamish to brownish in colour with minimum minute cracks present on the surface of the samples. The occlusal radiographs showed increase in distance between DEJ caused due to cracking and increased opacity of crown.

Teeth samples after incineration at 400^0c the crown showed greyish to blackish in colour, crack is seen near CEJ with chipped of enamel, and vertical crack is seen in root from CEJ towards bifurcation of the root. Root shows chalky white appearance. Under stereo-microscope the enamel of crown showed blackish grey to whitish colour change. At the areas where the enamel was chipped off and dentin was exposed, dentin was greyish in colour and cementum was whitish, enamel was separated with DEJ. The occlusal radiographs showed increase in distance between DEJ & CEJ (moderate) due to cause of crack in the crown portion at the crown to root junction level.

Teeth samples at 600^0c post incineration dark grey or blackish in colour of crown followed by detachment of crown from the root and torn into pieces was seen. The stereo-microscope showed brownish to blackish greasy shine in colour of teeth samples exposed at 600^0c, enamel chipped off, dentin blackish in colour was observed. Under occlusal radiographs of teeth samples post incinerated at 600^0c showed fracture of teeth at DEJ.

Teeth samples incinerated at 800^0c showed multiple fractures and samples torn into pieces when observed under naked eyes. But under stereo-microscope the teeth samples incinerated at 800^0c showed cracks extending from CEJ towards the root, colour was greyish silvery. The occlusal radiographs of teeth samples incinerated at 800^0c were severely damaged tooth torn into small pieces and fracture of tooth at CEJ.

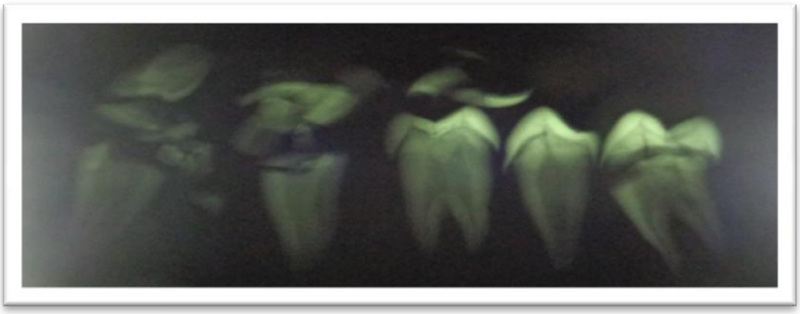

Fig. 5 : Increase in distance between DEJ, following with the cracks at 200^0c

Fig. 6 : Increase in distance between DEJ & CEJ (moderate) at 400^0c

Fig. 7: Fracture of teeth at DEJ at 600^0C

Fig. 8: showing seperation of crown from the root at 800^{0}C.

Discussion:

Fire is a leading cause of mortality and morbidity in adults and children. Investigators have long recognised the forensic potential of evaluating charred dental remains, as they yield important data regarding not only individual identity, but also circumstances surrounding the fire. Children are more susceptible to the fatal effects of fires because of their inability to safely evacuate themselves. A child's risk is further increased due to their smaller airways which is associated with a greater incidence of mucous obstruction.[17]

During fire incidents, the anterior teeth receive the greatest impact in-vivo, with the maximum protection to posterior teeth. The lips and cheeks initially provide some insulation until the muscles contract with increasing heat and drawback to expose the anterior dentition. The tongue also gives some protection to the lingual aspect of the lower dentition. The alveolar bone and the gingivae also provide additional heat protection for the roots. Therefore, these findings should be taken into consideration as a majority of experimentation has been done on extracted teeth. The dental remains retain some degree of their anatomical configuration following burning but are reduced in size and extremely fragile. The colour changes that occur during incineration may be useful in order to predict the degree of fragility of the dental tissues. In general, the teeth that have a dark or charred appearance are not as delicate as those that are 'porcelain white' in appearance.[38]

Changes in the color of burnt teeth can provide information on their fragility and recovery, trauma history, structural changes, and DNA degradation and on the temperature to which they were exposed. Teeth exposed to lower temperatures and/or shorter periods of heat tend to be dark black or brown, turning blue–gray, then stark and chalky white as the temperature and/or its duration increases. In most studies, tooth colour was measured visually using shade guides (e.g., the Munsell Colour Chart); however, besides being a subjective method, post incineration colours did not always correspond to the shades offered.[5]

. In this study the teeth 8were introduced in the oven at the experimental temperatures to simulate a thermal shock that would be induced by a fire, after 10 minutes exposure they were removed.

In the present study when observed samples incinerated at 200^0c under naked eye and stereo-microscoped showed features such as; crown with greyish to brownish in colour with minute chip of enamel portion, dentin shows greyish to blackish in colour, 1/3rd of the crown was destroyed. Root shows greyish to brownish in colour with horizontal cracks visible around the CEJ. Teeth samples after incineration at 400^0c the crown showed greyish to blackish in colour, crack is seen near CEJ with chipped of enamel, and vertical crack is seen in root from CEJ towards bifurcation of the root. Root shows chalky white appearance. Teeth samples at 600^0c post incineration dark grey or blackish in colour of crown followed by detachment of crown from the root and torn into pieces was seen. Teeth samples incinerated at 800^0c showed multiple fractures and samples torn into pieces when observed under naked eyes.

In a study done by **Karkhanis et al. (2009)**[17] the teeth incinerated at 200^0C were characterised by surface bubbling on the root, which was a shiny black colour. The enamel and dentin began to separate at 400^0c and the very pale brown enamel shell had disintegrated into numerous fragments. The teeth were extremely fragile after exposure to 600^0C and the cementum colour had changed to bluish black. Despite the fissuring at 800^0c the surface characteristics of the bluish gray enamel were still identified on the fragments.

Our results cannot be compared with their study, as they had used Scanning electron microscopy and colorimetric analysis.

Another study done by **Rubio et al (2015)**[5] at 200^0C, all the samples exhibited horizontal and vertical fissures; craze lines were also observed on the crown surface and the enamel had chipped off the cervical margin in 40% of the sample. The enamel shell of all samples exposed to 400^0C had separated completely from the underlying dentin in the cervical area. Deep fissures were observed and fine cracks were present in 90% of the samples. In only one case, the enamel was separated of the dentin. At 600^0C, the enamel and dentin had separated in 70% of the samples, and a chequered network of fine cracks was observed in 60% of the sample. The fragmentation of the coronal portion of the teeth (60%)

and crown-root separation (20%) was observed. At 800^{0}C, similar structural changes were observed although chequered pattern was exhibited in 100% of the crowns.

While in this study, the teeth incinerated at 200^{0}c were characterised by greyish to brownish discoloration of the root. Around CEJ separation of enamel and dentin is seen with chalky white appearance of the teeth at 400^{0}C. The teeth were become fragile and crown is detached from the root and torn into pieces at 600^{0}C, multiple fractures can be seen and colour changes to dark grey to blackish in colour at 800^{0}C.

In a review on changes seen in incinerated teeth by **Ressu et al. (2015)**[38] have emphasized that first change to enamel, dentine and cementum was darkening to a greyish-brown, when they were exposed to 300^{0}C. As the temperature increased to 500^{0}C, dentine appeared ‘dark greyish-black. The enamel appeared grey in both the permanent and deciduous dentition but the surface of deciduous enamel was observed to have lost its sheen. At 900^{0}C, they were all described as being ‘almost white’, progressing to ‘porcelain white’ at 1000^{0}C and above. There were no microscopic changes in permanent teeth when subjected to temperatures up to 200^{0}c, but in deciduous teeth there was early evidence of fragmentation in enamel at 100^{0}c, long before the teeth were seen to darken. It was noted that from 300^{0}c-500^{0}c, enamel and cementum start to fissure and fragments. Dentine, however, manages to maintain its integrity, and only shows evidence of tubular narrowing at 700^{0}c. While in deciduous dentine, this change is seen much earlier, at 300^{0}c. The dentinal tubules in permanent and deciduous dentition retain their principle structure until 1100^{0}c. In enamel and cementum, the formation of granules appear much earlier at 700^{0}c and persist until around 1000^{0}c when both tissues lose their characteristic structure. The enamel is invariably lost from the dentine and the cementum becomes a homologous mass covering the root. When a temperature of 1300^{0}c is reached, all of the tissues in the permanent dentition have lost their structure.

But in the present study deciduous teeth are not used and temperatures were not exceeded above 800^{0}c as there was difficulty in handling the incinerated specimens to carry from one place to another for further analysis.

Priyanka et al. (2015)[3] in their study have observed that teeth were not strongly affected by the temperature exposure till 100°C. Above 300°C the radiographic changes observed were a progressive formation of fissures between enamel and dentin, fractures between enamel-dentin and within dentin, large fractures spreading through the dentin and crown crushing at 1000°C.

In another study by **Merlati (2002)**[11] at a temperature of 200^0c, the teeth did not show signs of fractures. As the temperature increased, cracks, fissures and fragmentation of both the crown and the root occurred, although in two cases, at 600 and 800^0 C, the teeth fractured when handled. This highlights two important points: first, that calcined teeth, being completely dehydrated, are very delicate, and secondly, that fractures may precede the fire because in real-life situations trauma is often associated with the high temperatures caused by major fires.

According to the results obtained in a study by **Shekhawat et al. (2016)**[2], teeth irrespective of any age group, which remained exposed to gradual increments of temperature, experienced less structural damage than teeth exposed to a sudden higher temperature. In their study, the crowns of teeth exhibited a change in color ranging from whitish (200^0C) to blackish discoloration (400^0C) to grayish white (600^0C), when exposed to high temperatures.

On the contrary, a study conducted by **Moreno et al. in 2009**[24] reported a change in color to light brown at 200^0C. They also observed that teeth were not strongly affected by the temperature exposure till 200^0C. However above 200^0C, the teeth were affected by a progressive formation of fissures. The authors emphasized that the controlled increment of temperature and careful handling of the specimens allowed us to observe the morphology of the tissues, a view also highlighted by **Fereira et al. in 2008**.[31]

According to **Moreno et al.,**[24] who observed that in reality many other factors may complicate the effect of fire, such as the time of exposure to fire, the type of fire, the source of fire, the speed of increase in temperature, and the material used to extinguish the fire.

Sandholzer et al. 2014[4] explain that the different material properties of dentin and enamel cause a separation and fragmentation of the crown between 400 and 500^0C. The partial or full debonding of the crown alongside the dentin-enamel junction is strongly related to the final temperature and heat-induced dentinal shrinkage. In total, four specimens of the 650^0C and 800^0C temperature group had a completely fragmented crown.

Further study required such as microscopic analysis etc for the factors discussed above.

Conclusion-

Burn victim identification highlight the need to employ faster and more accurate methods during the process of identification. For which teeth and tooth complex represent an excellent source, which is protected by physical and chemical barriers of protein mineral matrix of bone in case of incineration.

The examination of teeth in the study provides valuable information about temperatures a fire victim might be exposed to. It was interesting to note that experimental conditions have some limitations as the present study did not accurately represent the real-life scenario of a fire, explosion, etc. This study also did not take into account other possible variables present in reality, such as protection from direct exposure provided by structures such as hard and soft tissues surrounding the teeth. Further experiments are required that make into consideration the factors discussed above. Studies that focus on experimental setups which are closer to real life scenarios is the need of the hour.

Morphologic and radiologic alterations caused by fire may provide useful information about the temperature and duration of exposure to fire. It can also aid in understanding the circumstances surrounding the fire. This study can help the forensic investigators in preplanning the systematic approach toward the preservation of incinerated dentition, as it could prove to be the best evidence for identification of those who are extensively burned.

Conflict of intrest- none.

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