REVIEW ARTICLE

Role of conservative dentistry and endodontics in forensic odontology

Gaudam.V.G[1], Gagan deep Kaur[2],Shraddha Gupta[3],Raina Rastogi[1]

Abstract

Dental hard tissues are extremely resistant to decay, fire, natural calamities, etc., are usually the only remains after an extended period of burial. Since the late 1890s, forensic dentistry has gradually established itself as important, often indispensable, in medico-legal cases, in particular for identification of the dead. The specialty of forensic dentistry generally covers three basic areas, namely,

- *Identifications of human remains*
- *Litigation relating to malpractice*
- *Criminal proceedings, primarily in the areas of bite-mark evaluation and abuse cases especially child abuse.*

Human dentition is considered as hard tissue analog to the fingerprint. It is almost as unique to an individual as a fingerprint. Teeth with their physiological variation and effects of therapy remains to records throughout their lifetime.

Keywords: Antemortem, Postmortem, Age Estimation, Radiographic Records, Burned Victims

INTRODUCTION

Conservative dentistry and endodontics is the speciality of dentistry concerned with the etiology, prevention, diagnosis, and treatment of conditions that affect the tooth pulp, root and periapical tissues. This speciality is utilized for identification of individuals through restorations and root canal fillings.[1] Presumably, individuals with numerous and complex restorations are often easier to identify than those individuals with little or no restoration.[2] Restorations play a significant role to aid in the identification process, as various restorative materials have varying resistance to high temperatures.[3] Application of endodontic data for identification of individuals in forensic odontology is on the rise. This trend can be mostly attributed to the routine radiographic recording of data and persistence of the materials employed in root canal obturation , many of which are capable of surviving an incineration attack. [4]

1. *Post graduate student*
2. *Professor*
3. *Reader*

Department of Conservative dentistry and Endodontics
Kothiwal dental college & research centre
Moradabad, uttar Pradesh

Correspondence Address

Gaudam.V.G.
Department of Conservative Dentistry and Endodontics
Kothiwal Dental College & Rresearch centre
Moradabad, Uttar Pradesh

From a forensic scope, endodontics plays a valuable role in providing solid ante-mortem (AM) radiographic evidence for comparison with post-mortem findings in human identifications.[5]Forensic odontology is a special branch of dentistry that works in parallel with the courts, providing evidence to elucidate civil and criminal circumstances.[6] Specifically, forensic dentists play an essential part in the identification of charred, putrefied, decomposed bodies, as well as of skeletal remains, in which fingerprints are no longer available.The dental identification of humans is often performed through a comparative approach.[7] Basically, ante-mortem (AM) data obtained from records of dental treatments (e.g. radiographs, written records, dental casts, and photographs) are collected from private clinics and compared with post-mortem (PM) data obtained during cadaveric examinations.[8] In this context, Endodontics emerges as a potential source of AM data, once the steps of endodontic interventions are systematically recorded into the clinical files together with detailed registration of imaging examinations.[9] This specific source of AM data enables the detection of unique features, such as the radiographic morphology of the pulp chambers and root canals, the height of alveolar bone crests, the stage of root formation, and the presence of dilacerations and periapical lesions,[9,10] Understanding of the root canal anatomy and its variations

1.Knowledge on root and root canal anatomical variations:

In the human dentition, a wide range of anatomical variations in each tooth type has been reported.[11] For instance, the occurrence of supernumerary roots in the primary and permanent human dentition is well documented and the prevalence can reach up to >30% in mandibular molars, and current reports continue to demonstrate high

percentages of middle mesial canals in mandibular molars, more common occurrence of double and three canals in anterior teeth and maxillary premolars than previously reported, respectively.[12-17] Therefore, a forensic odontologist should be aware of such anatomical variations and their radiographic landmarks, which may facilitate postmortem personal identification when compared to ante-mortem records.[18] The application of cone-beam computed tomography (CBCT) can help the forensic odontologist to identify such anatomical variations. [19]

2. RESTORATIONS:

Several studies using dental radiographs are recorded regarding the successful use of dental restorations for the purpose of identification. In relation to the pattern of the amalgam restoration, the measure of uniqueness of patterns of amalgam restoration in the upper and lower dentition was investigated by Philips who found that patterns of amalgam restoration in the first molar were relatively common and therefore had a low measure of uniqueness. However if the pattern of the amalgam restoration in the first molar was combined with the patterns in one or more other teeth, then uniqueness increased markedly and improved the likelihood of identification of that person.[20] In a study by Borman and Grondahi(1990), the radiographic appearance of teeth and restorations of two sets of bite- wing radiographs were compared by seven dentally-trained observers. The question asked was whether the radiographic image of a single compound amalgam restoration in a posterior teeth was unique. All seven observers were asked to identify all of the cases where simple restorations were present. The results showed that mistakes were made by a total of five of the seven Observers.[21] The relatively recent trend for aesthetic dentistry has resulted in the introduction of tooth-coloured composite materials to replace amalgam. This has opened up a new area of research regarding the radiographic assessment of composite materials for purposes of identification. Nonetheless if it can be demonstrated that both the ante and post-mortem radiographs of a single composite restoration in the same tooth show the same morphology, this uniqueness can be used for purposes of identification.[22,23]

3.ENDODONTIC RADIOGRAPHS:

Forrest and Wu ET AL [55] 2010, have highlighted that radiographs are the most reliable source of AM data for human identifications, as they enable comparison with PM findings. In addition, tooth roots preserve morphological information for a longer time when compared with dental crowns,[8] which constantly undergo dental interventions. During endodontic treatment planning, this morphological information is radiographically recorded, and can be later used for forensic purposes.[5] Periapical radiographs also are useful to identify root canal filling materials such as gutta-percha, silver points, root canal sealers in addition to metallic and fiber posts, and post endodontic coronal restorations. The complexity and variability in post design and placement, core material, and coronal restorations provide further individuating features to each such treated tooth.[8] A study conducted by Khalid et al demonstrated that the discriminatory characteristics of the radiographic images of obturated single root canals is so significant that it could be unique and used as a tool for purposes of identification**.** Post-mortem radiographs are ideally taken in a way that the original conditions presented in a ante-mortem image are duplicated as closely as possible, and the similarity between the two images can be confirmed by superimposition.[8] Peri-apical radiographs also are useful to identify root canal filling materials such as gutta-percha, silver points, root canal sealers in addition to metallic and fiber posts, and post-endodontic coronal restorations.[8] It is worth noting that comparison of dental anatomical features in the absence of dental/endodontic restorations is more complex than when such evidence is present.

4. ENDODONTIC MATERIALS:

An endodontically treated tooth potentially contains more individuating information than a non-endodontically treated tooth, and as a result is a richer source of comparative image data. The basic root filling consists of a cement sealer and a core filling material, most commonly gutta-percha. Other root fillings are silver points and most recently resin-based core filling materials. Zinc-oxide eugenol, resin, glass ionomer, silicone and calcium hydroxide are group classifications for endodontic sealers. The obturation of root canals, and hence post-preparation anatomy, will be demonstrated by the radio-opacity of these materials in a post-treatment radiograph. Endodontic posts may be indicated in some circumstances. These posts may be active or passive, tapered or parallel, and prefabricated or custom cast. Nickel-Chromium alloy, stainless steel, titanium alloy, ceramic, zirconium and carbon fibre are materials commonly used in post fabrication.[8] Also, one of the study demonstrates that the morphology of an obturated single root canal is easily identifiable by comparison of ante and post-mortem radiographs. Obturation of single-rooted teeth using gutta-percha creates a unique pattern that can be easily recognised using radiographs.

The following table shows the radiographic appearances of various restorative and endodontic filling materials:

Table:3

RADIOPAQUE	SLIGHTLY RADIOPAQUE	RADIOLUCENT
Metallic Restorations (amalgam and gold), Stainless Steel and Chrome Crowns, Base Materials, Metallic Pins, Gutta Percha, Silver Points	Porcelain Restorations, Composite Restorations	Composite Restorations, Acrylic Restorations

This study also suggests that it is highly unlikely for two obturated single-root canals to have exactly the same radiographic appearance.[24]Teeth are components that often survive severe fires because of their particularly resistant composition, influenced by the protection provided by the

soft tissues of the face. In fact, only fragments of teeth are often available, and obtaining their radiographs is therefore more important. A study examined the behavior of endodontically treated teeth under thermal stresses, and results showed that the obturation material can be recognizable till 1100°C; however, a "honeycomb" appearance (radiolucent areas within the endodontic treatments) was observed over 600°C as a result of the softening of the obturation material, which can even flow to fill the missing root canals. Changes in the shape and dimension of the obturation material, especially if defective, can also be observed at lower temperatures. Broken files can also be observed at such elevated temperatures. Intracoronal restorations, such as amalgam and resin composite fillings, can also maintain their integrity at elevated temperatures.[25] Other investigators have examined the physical changes in endodontically treated teeth in materials after their exposition to high temperatures of up to 1000°C.[26] Results showed that dental tissues and materials offer great resistance to high temperatures. However, at temperatures above 800°C, endodontic materials (gutta-percha/zinc oxide eugenol and gutta-percha/resin cement combinations) tend to change to chalk-like whitish hue, which is difficult to recognize from the incinerated dentin.[26]

5. USE OF 3-DIMENSIONAL TECHNIQUES FOR DETERMINATION OF PULP CANAL AND AGE EXTIMATION:

The pulp-dentinal complex shows physiological changes that mainly result in the reduction of the pulp chamber volume resulting from the continual deposition of secondary dentin.[27] Forensic scientists have been using the decrease in size of the pulp chamber for a long time as an important marker for identifying the age of individuals. Panoramic and periapical radiography provides a valid nondestructive approach for age estimation. However, the edges of the pulp usually become blurred, and the diffuse edges could thus cause differences between the measurements of the same tooth by different observers when the three-dimensional (3D) pulp is reproduced in a two-dimensional radiograph.[27,28] The analysis of the volumes of the pulp chamber and the tooth is more reliable than the calculation of areas, possibly because secondary dentin formation may not be uniform along all pulp surfaces, and therefore, measurements of projected areas could provide an incorrect impression of the extent of this process.[29] Existing projects utilize 3D diagnostic modalities to examine the relationship between age and age-related changes in pulp–tooth volume ratio with the use of micro-CT.[28,30] Several studies have also confirmed that CBCT allows for the accurate calculation of tooth volumes, and the method is highly reproducible because of the good inter-examiner agreement.[27,29,31,32]

Figure 1: a) A sample of an extracted mandibular first molar tooth.b) An access cavity was prepared, and the distal root was obturated using a single cone (gutta percha size 30 – 0.04 taper). The mesial root was left untreated, and the access cavity was restored. The sample was introduced in a furnace at 500°C for 20 mins. c) After cooling, the sample showed fracture of the crown into pieces, and the colour turned black. d) A periapical radiograph showing the effect of heat on the gutta percha in which the spaces left from inadequate obturation in the distal root were filled by the molten gutta percha leaving some voids (yellow arrow). The molten gutta percha was able to go few millimeters into the mesial orifices (white arrow)

6. Real life endodontic implications in forensic odontology:

Rhonan Ferreira Silva et al,[5] conducted a study that describes three cases of unknown male victims of murder examined between 2009 and 2012, at the medico-legal institute of Goiás, Central-Western Brazil.

CASE:1

In 2009, a highly decomposed body was found near a river. After crime scene investigation, the body was referred for an autopsy. Dental examination revealed a nonmetallic restoration in the mandibular left first premolar (#34), a decayed mandibular left second premolar (#35), a metallic restoration in the mandibular right first premolar (#44), and missing molars [Figure 2]. The mandible was dissected to allow adequate PM radiographic examination, which revealed root canal treatment in the tooth #34 [Figure 3]. Police investigations suggested that the body belonged to a 30-year-old man, missing for 15 days. Relatives of the potential victim were asked to provide any AM medical record. Periapical radiographs dated from 2008 were obtained and showed evidence of root canal treatment performed in the tooth #34 Moreover, both AM (2008) and PM (2009) radiographs showed the same morphology of the mandibular left first and second premolars, as well as missing molars. Additional similarities were detected when analyzing alveolar bone loss in the region of the mandibular left molars.[5]

Figure:2 Postmortem photograph of the mandible of the victim incase

Figure:3 Comparison between (a) post-mortem (2009) and (b) ante-mortem (2008) periapical radiographs, revealing root canal treatment in the mandibular left first premolar and similar morphological structure adjacent to the mandibular left second premolar.

CASE 2:

In 2011, a body was also found in highly decomposed state,again near a river. Dental autopsy revealed several decayed teeth; teeth restored with nonmetallic materials; and empty sockets in the anterior region of the mandible [Figure 4]. Radiographically, the victim presented slight dilacerations of the mandibular right second premolar (#45); root canal treatment in the mandibular right first molar (#46);incomplete root development of the mandibular right second (#47) and third molars (#48); and alveolar bone crest extending obliquely from the mandibular right second premolar (#45) to the mandibular right firstmolar (#46) [Figure 5]. The search for compatible AM data resulted in endodontic pre and post-operative periapical radiographs, dated from 2009, related to the treatment of the tooth #46 [Figure 5]. In addition, the images revealed that the teeth #45, #47, and #48 presented incomplete root development. Alveolar bone crest extending obliquely from the tooth #45 to thetooth #46 was also detected. Positive dental identification was achieved considering the matching evidence of dental interventions (endodontic treatment) and morphological traits. Additional confirmation was obtained in the dental age estimation process, which revealed a time interval of approximately 2 years for root development of the teeth#47 and #48, compatible with the period elapsed from 2008 to 2011. [52]

Figure:4 post mortem photograph of the mandible of the victim in 2011

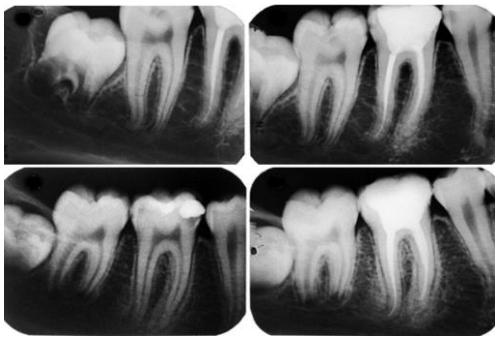

Figure 5: Comparison between (a and b) postmortem (2011) and (c and d) ante-mortem (2009) periapical radiographs, revealing endodontic treatment in the mandibular right first molar, dilaceration of the mandibular right second premolar, and incomplete root formation in the mandibular right third molar

CASE 3:

In 2012, a body was found in the countryside. Anthropological examinations on the skull and pelvic bones indicated compatibility with an unknown adult male. On dental autopsy, only a maxillary right first molar (#16) with a metallic crown was detected [Figure 6]. Radiographically, endodontic treatment of the tooth #16 was detected, as well as an impactedmaxillary canine (#13) transversely positioned [Figure 7]. Police investigations indicated an initial compatibility between the skeletal remains and a 45-year-old male, missing for 60 days. Relatives of the potential victim provided periapical radiographs and a clinical file containing details of endodontic interventions performed in 2008. Moreover, radiographs establishing endodontic working length, and assessing the postoperative outcome of the tooth #16, revealed the apex of the tooth #13 Both teeth presented unique traits, which positively matched PM findings during the comparative procedure, leading to the positive identification of the victim. [52]

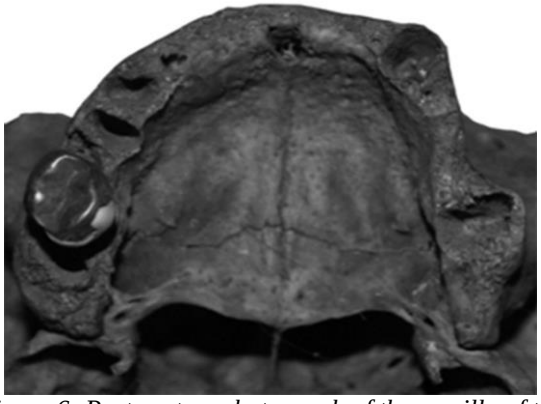

Figure 6: Postmortem photograph of the maxilla of the victim in case 3 (2012)

Figure 7: Comparison between (a) postmortem (2012) and (b and c) ante-mortem (2008) endodontic radiographs, revealing endodontic treatment in the maxillary right first molar and the apex of a transversely impacted maxillary right canine

CASE 4: ENDODONTICS IN IDENTIFICATION OF BURNED VICTIMS:

CASE HISTORY:

Just prior to limiting his practice to endodontics in 1965, the author had a 31-year-old male patient referred to the office for routine dental care. **A** full-mouth series of radiographs of this patient revealed a chronic asymptomatic lesion at the apex of the upper right lateral incisor (Fig. 8). Endodontic therapy was initiated and the canal was cleaned and shaped and then sealedwith a medicated dressing. On the second visit the canal was obturated using lateral and vertical condensation with gutta-percha and Kerr's Pulp Canal Sealer, Rickert's Formula (Fig. 9).The patient was recalled six months later for a check-up examination. The radiograph (Fig. 10***)*** revealed good osteogenesis, and there was an absence of any discomfort, mucosal fistulae, or any other untoward symptoms. The patient never returned for any further dental care and contact with this patient was lost.[33]

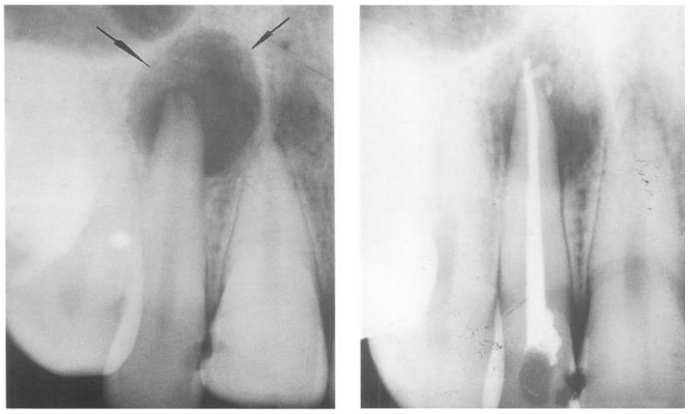

Figure 8: Periapical film of non-vital upper right lateral operative radiograph of Incisor with a large radioluscent area

Figure 9: immediate post endodontic treatment of right lateral incisor

Approximately four years later, the home of this patient was completely consumed by an intense fire. The conflagration was so severe that metal portions of his automobile located in his garage were melted. The patient's male companion was not at home at the time. Remains of a body were found, placed in a rubber-type bag and transported to a local mortuary. The police and coroner were summoned to this case to help identify the remains. They contacted the author who had been the general dentist of the alleged victim four years prior.[33]

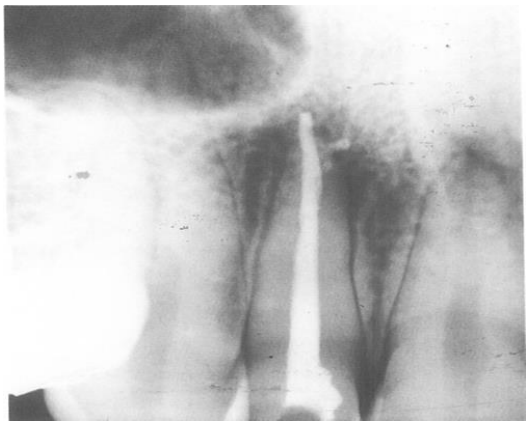

Figure 10: A 6-month recall/.film illustrating osteogenesis

The law enforcement personnel could not locate any other dentist that this burn victim had visited. The author was notified to come to the mortuary to help identify the victim. It **is** to be understood that the author had never identified a deceased person before. When viewing the remains in the body container, only water-soaked charred coal-like ashes of skeletal bone fragments were observed. There was no soft tissue or any resemblance to a human figure. After about two hours of searching for any facial or dental remains, a small delicate portion of the anterior part of the maxilla, a

piece of posterior portion of the right maxilla with two roots (one root had an alloy clinging to the dentine), and an interesting blackened anterior root were picked out. Except for the root, the above fragments were exceedingly friable and very delicate. These brittle pieces were placed in a box lined with soft cotton wool and taken to the dental office accompanied by a detective.[33]

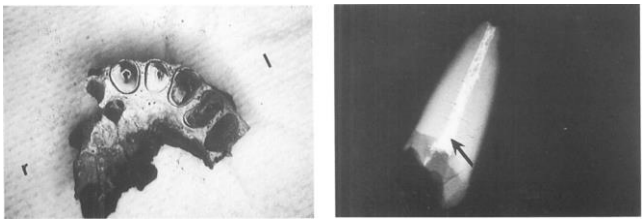

Figure 11: Portion of the anterior maxilla of the burn victim. Note roots Of left anteriors remaining. all teeth missing on right side.
Figure 12: Radiograph of the root discovered in the remains. This illustrates a radiopaque material in the canal space (Arrow)

All teeth on the right side were gone. Only the roots of the left anteriors and two bicuspids were present. The anterior root exhibited sonic whitish substance in the canal orifice and a radiograph indicated some sort of precipitate or ash in the canal space (Fig. 11). The portion of the right posterior maxilla with roots was radiographed (Fig. 12). (Note: this fragment disintegrated in handling during this procedure.) When comparing the upper molar radiograph (Fig. 13***)*** of the patient record, the outline of the occlusal alloy of the second molar and the curvature of the third molar root show distinct similarities.

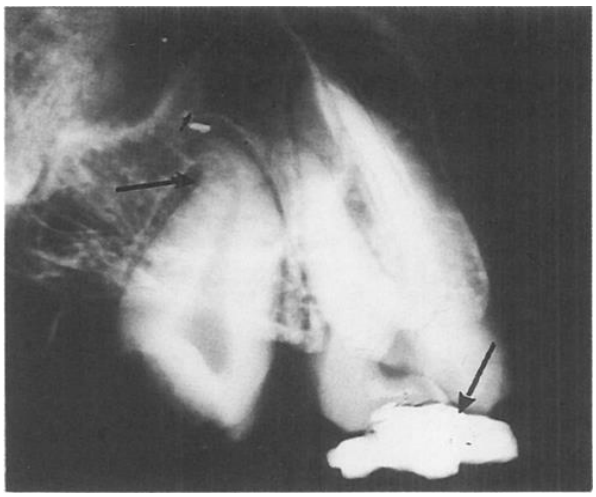

*Figure 13: Radiograph of a portion of the upper right maxilla found showing **a** second molar and a third molar root*

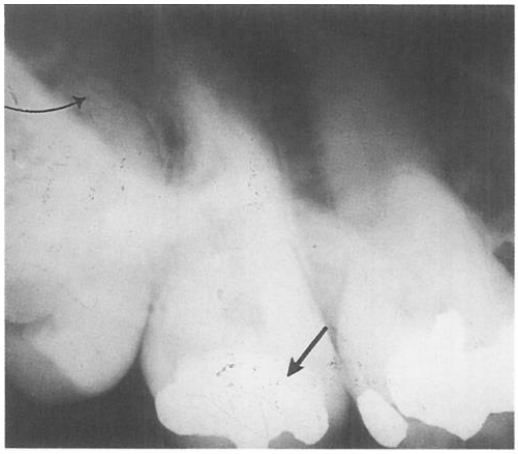

Figure 14: Radiograph ofthe upper right molar from the patient record. Note similarities relative to Figure 25 (arrows).

All of the bony remnants were then taken back to the mortuary by the law enforcement officer. After comparing all of the above evidence and the full mouth series with the photographs and radiographs, it was difficult to make a positive identification. Only that root with the whitish substance remained a mystery.[33]

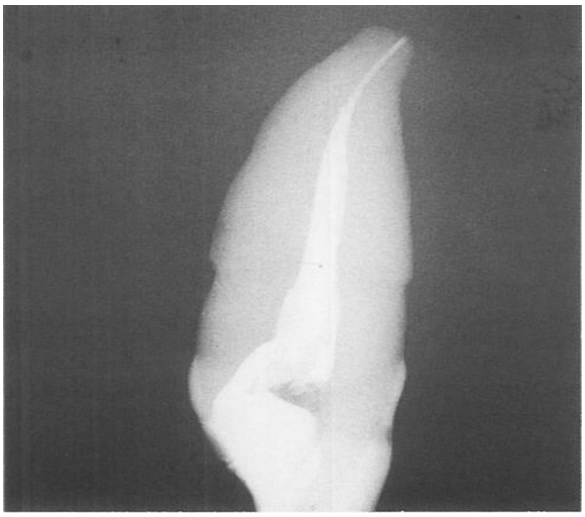

Figure 15: Radiograph of root-filled test tooth

About two weeks after the tragedy, the author received a subpoena to appear at a coroner's inquest .A coroner's inquest is an inquisition or examination into the causes and circumstances of any death happening by violence or under suspicious conditions, held by the coroner, often with the assistance of a jury**.** The news media had discovered that the victim's roommate had taken out a $100,000 life insurance policy on the alleged victim about one year before the fire. The insurance company was reluctant to compensate for the death of this person because they doubted the identity of the

insured .When all the evidence, the piece of maxilla, the root with the ash of the root canal filling, together with the experimental tooth including photos and radiographs, were presented at the inquest, the decision handed down was that the person consumed in the fire was the same as the patient of the author. There was no evidence to indicate that arson was committed.[33] It is a known fact that in fires of extremely high temperatures, there are no recognisable soft tissues remaining in persons killed under these conditions. Also the crowns of the teeth fall away from the roots because these portions are directly exposed to the extreme heat. The roots are somewhat protected by the alveolar bone housing and can remain intact. The extreme fragility of the charred calcified remains is well documented**.** However, a review of forensic dental literature does not have much information on endodontically treated teeth in burn victims. Wilson and Massey have done extensive research with scanning electron microscopy on the effect of high heat on dental tissues. Their findings were concentrated on the effect of high heat on dentine and enamel. The stabilization and transportation of fragile human bony fragments are described in an excellent monograph by Grifiths and Bellamy. These authors emphasize the importance of obtaining radiographs of the affected bones and teeth. An effort should be made to position the pieces as closely as possible to the angulations normally found in the mouth. Much research has been done on the effects on teeth and dental restorative materials in burn victims. Gustafson has performed many studies on victims burned to ash. He found that roots with the crowns missing are often the only identifiable evidence. He states that if the teeth are protected by the soft tissues or even the alveolar bone, the roots can withstand these extreme high temperatures. Amalgam fillings can often resist intense heat if they are not directly exposed. Variations do occur because of the differences in the amount of mercury in the amalgam composition, as mercury tends to vaporise under these elevated temperatures. Again, there is no mention of root canal materials in the burn cases discussed. Harsini (6) studied the effect of temperatures from 20G 1300"C on dentine and enamel using electron microscopy. He was able to determine the temperatures of the heat based on the microscopic changes occurring in the dentine and enamel.[33]

.

*Figure **16:** The tooth in Figure 33 after cooling. Note brittleness and friability with the crown disintegrated.*

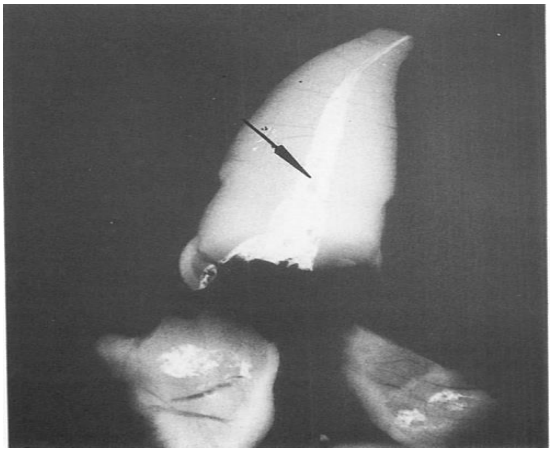

*Figure 17: Radiograph of tooth heated to 538°C (1000°F). Note the radiopaque material in canal space which **is** almost identical to that in figure 15*

7. CONCLUSION:

Despite the constant enhancement of dental techniques, materials and facilities, the conventional radiographs, routinely performed in the clinical practice, are still the most common source of forensic ante-mortem data for the human identification process. In this context, Endodontics becomes a valuable specialty in the forensic scope, once periapical radiographs are performed. Dentists have a major role to play in keeping accurate dental records and providing all necessary information so that legal authorities may recognize malpractice, negligence, fraud or abuse, and identify unknown humans. It is imperative that dental evidence should not be destroyed through erroneous handling until appropriate radiographs, photographs, or impressions can be fabricated. Proper methods of physical stabilization of incinerated human dental remains should be followed. The maintenance of integrity of extremely fragile structures is crucial to the successful confirmation of identity.[34] Adequate knowledge on root and root canal variations is essential for forensic personal identification. The application of 3D technological advances provides a more accurate method for age determination, and assessment of the root and root canal morphology for forensic identification of compromised human skeletal remains. The properties of current endodontic materials challenged at elevated temperatures should be further investigated. Endodontists should be aware of their responsibilities that can aid in forensic personal identification.[35] The increase in the instances where endodontic data proves crucial in human identification suggests that the role of and endodontist might be extended beyond the lifetime of a patient. There might be situations wherein endodontic evidence might be the only source of identification due to high survival capability of dental hard tissues and endodontic materials. Hence endodontists should be keen on image protection and maintaining accurate records regarding the materials used for individual cases.[4] Increasing trend of performing human

identification supported by endodontic evidence indicates that justice is aware of the usefulness of endodontics as a source of AM data. As a result, endodontists may be asked to support the law in the face of violent crimes, especially murders. Based on that, awareness of the importance of performing adequate radiographic techniques and recording them becomes essential. Moreover, dentists should keep up with new technologies for the management of conventional and digital radiographs, and for the proper recording and storing of endodontic data. [5] The radiographic images of the obturated canals of single-rooted teeth were shown to have highly specific morphological features that could act as a potential aid for purposes of identification. The discriminatory potential of the unique morphology of the obturated canal of a single-rooted tooth could be used for evidence-based decision making in Forensic Dentistry. [90]The results of the present survey revealed that 6% of total participants had good awareness (>16 Qs), 62% of total participants showed moderate awareness (10-16 Qs) and 32% of total participants had poor awareness (<10 Qs). By considering the present expansion in the field of forensic odontology, endodontists should be knowledgeable of the role of their specialization in forensic odontology.[36]

8. FUTURE TRENDS:

Inspite of the increasing use of tooth tissues in forensic investigations, little literature is available on the processes of decomposition of these mineralized tissues, on the location of DNA following post-mortem diagnosis, or on the outcomes of various sampling techniques. Further in-depth investigation is required to understand the interaction between tooth mineral and DNA and how this changes in the post-mortem environment. Assessments of post-mortem changes in teeth over a time period applicable to forensic investigations would also be extremely valuable. This knowledge would allow the more appropriate selection of tissue for DNA extraction, as well as a more-informed choice of technique used to liberate the DNA, increasing the efficiency of the extraction process.[37]

REFERENCES

1. Shamim T. A new working classification proposed for forensic odontology. *J Coll Physicians Surg Pak* 2011; **21**:59.
2. Avon SL. Forensic odontology: the roles and responsibilities of the dentist. *J Can Dent Assoc* 2004; **70**:453-8.
3. Bose RS, Mohan B, Lakshminarayanan L. Effects of elevated temperatures on various restorative materials: *an in vitro* study. *Indian J Dent Res* 2005; **16**:56-60
4. Greeshma Lal Manjadiyil, Dr.Harish S Shetty, Dr Shakkira Moosakutty, Dr Jeslee Ann Jose, "Role of Endodontics in Forensic Odnotology - A Review", IJDSIR- February - 2020, Vol. – 3, Issue -1, P. No. 26 - 30.
5. Silva RF, Franco A, Mendes SD, Picoli FF, Nunes FG, Estrela C. Identifying murder victims with endodontic radiographs. Journal of forensic dental sciences. 2016 Sep;8(3):167.
6. Silva RF, Nunes FG, Faria Neto JC, Rege IC, Junior ED. Forensic importance of panoramic radiographs for human identification. Rev Gaucha Odontol. 2012;60:527–31. [Google Scholar]
7. Silva RF, Franco A, Dias PE, Gonçalves AS, Paranhos LR. Interrelationship between forensic radiology and forensic odontology – A case report of identified skeletal remains. J Forensic Radiol Imaging. 2013;1:201–6. [Google Scholar]
8. Forrest AS, Wu HY. Endodontic imaging as an aid to forensic personal identification. Aust Endod J. 2010;36:87–94. [PubMed] [Google Scholar]
9. Silva RF, Franco A, Picoli FF, Nunes FG, Estrela C. Dental identification through endodontic radiographic records: A case report. Acta Stomatol Croat. 2014;48:147–50. [PMCfree article] [PubMed] [Google Scholar]
10. Spyropoulos ND, Liakakoy P. The use of periapical x-rays in the identification of a corpse. Hell Stomatol Chron. 1990;34:151 [PubMed] [Google Scholar]
11. Ahmed HM. A paradigm evolution shift in the endodontic map. Eur J Gen Dent 2015;4;98
12. de Pablo OV, Estevez R, Péix Sánchez M, Heilborn C, Cohenca N. Root anatomy and canal configuration of the permanent mandibular first molar: A systematic review. J Endod 2010;36:1919-31.
13. Ahmed HM. Anatomical challenges, electronic working length determination and current developments in root canal preparation of primary molar teeth. Int Endod J 2013;46:1011-22.
14. Kim SY, Kim BS, Woo J, Kim Y. Morphology of mandibular first molars analyzed by cone-beam computed tomography in a Korean population: Variations in the number of roots and canals. J Endod 2013;39:1516-21
15. Ahmed HM, Cheung GS. Accessory roots and root canals in maxillary premolar teeth: A review of a critical endodontic challenge. ENDO Endod Prac Today 2012;6:7-18.
16. Azim AA, Deutsch AS, Solomon CS. Prevalence of middle mesial canals in mandibular molars after guided troughing under high magnification: An *In Vivo* investigation. J Endod 2015;41:164-8.
17. Ahmed HM, Hashem AA. Accessory roots and root canals in human anterior teeth: A review and clinical considerations. Int EndodJ 2016;49:724-36.
18. da Silva RF, do Prado MM, Botelho TL, Reges RV, Marinho DE. Anatomical variations in the permanent mandibular canine: Forensic importance. RSBO 2012;9:468-73.
19. Danforth RA, Herschaft EE, Weems RA. Dental, oral, and maxillofacial radiographic features of forensic interest. In: Senn DR, Weems RA, editors. Manual of

Forensic Odontology. USA: CRC Press Taylor and Francis; 2013. p. 129-57.
20. Phillips VM. The uniqueness of amalgam restorations for identification. J Forensic Odonto 1983; 1:33-8.
21. Bormann H, Grondahl HG. Accuracy in establishing identity by means of intra-oral radiographs. J Forensic Odonto 1990; 8:31- 6.
22. Phillips VM, H. Zondagh. The discrimination potential of radioopaque composite restorations for identification: part 3. J Forensic Odonto 2009; 27: 27-32.
23. Hemasathya BA, Balagopal S. A study of composite restorations as a tool in forensic identification. J Forensic Dent Sci. 2013; 5(1):35-41.
24. Khalid et al. Discrimination Potential of Root Canal Treated Tooth in Forensic Dentistry**.** JFOS. July 2016; Vol.34: 19 – 26.
25. Savio C, Merlati G, Danesino P, Fassina G, Menghini P. Radiographic evaluation of teeth subjected to high temperatures: Experimental study to aid identification processes. Forensic Sci Int 2006;158:108-16.
26. Vázquez L, Rodríguez P, Moreno F 2 nd . *In vitro* macroscopic analysis of dental tissues and some dental materials used in endodontics, submitted to high temperatures for forensic applications. Rev Odontol Mex 2012;16:171-81.
27. Pinchi V, Pradella F, Buti J, Baldinotti C, Focardi M, Norelli GA. A new age estimation procedure based on the 3D CBCT study of the pulp cavity and hard tissues of the teeth for forensic purposes:A pilot study. J Forensic Leg Med 2015;36:150-7.
28. Aboshi H, Takahashi T, Komuro T. Age estimation using microfocus X-ray computed tomography of lower premolars. Forensic Sci Int2010;200:35-40.
29. Porto LV, Celestino da Silva Neto J, Anjos Pontual AD, Catunda RQ. Evaluation of volumetric changes of teeth in a Brazilian population by using cone beam computed tomography. J Forensic Leg Med 2015;36:4-9.
30. Someda H, Saka H, Matsunaga S, Ide Y, Nakahara K, Hirata S, *et al.* Age estimation based on three-dimensional measurement of mandibular central incisors in Japanese. Forensic Sci Int 2009;185:110-4.
31. Star H, Thevissen P, Jacobs R, Fieuws S, Solheim T, Willems G. Human dental age estimation by calculation of pulp-tooth volume ratios yielded on clinically acquired cone beam computed tomography images of monoradicular teeth. J Forensic Sci 2011;56 Suppl 1:S77-82.
32. Yang F, Jacobs R, Willems G. Dental age estimation through volume matching of teeth imaged by cone-beam CT. Forensic Sci Int 2006;159 Suppl 1:S78-83
33. Weisman MI. Endodontics – A key to identification in forensic dentistry: Report of a case. Aus Endod Newsl 1996;22:9-12.
34. Pradnaya V, Seema D, Wavdhane M.B. Application of Endodontic Imaging Modalities in Forensic Personal Identification: A Review. Journal of Dental and Medical Sciences 2018.
35. Ahmed HM. Endodontics and forensic personal identification: An update. Eur J Gen Dent 2017;6:5-8.
36. Susmitha YRS, Yelapure M, Hegde MN, et al. Knowledge and awareness of role of endodontics in forensic odontology- a questionnaire based survey among postgraduate students. J. Evolution Med. Dent. Sci. 2020;9(05):262-265,
37. Thouseef CHV, Mustafa M, Jayakrishnan MJ. Forensic Odontology & Endodontics: Clinical Role & Perspectives. Saudi J Oral Dent Res 2019.