Review Article

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Dentistry Section

Restoring Teeth Aids in Restoring Identity- Role of Restorative Dentistry in Forensic Odontology

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ABSTRACT

Forensic odontology is a relatively new branch in the field of dentistry that has opened a new horizon for many dentists. With a surge of crime rates and lawsuits in the world, the need for specialists to help in identification of postmortem remains has increased. The reason for forensic odontology as an up-and-coming field in recent times is because teeth and the surrounding orofacial structures, similar to fingerprints, are unique features and can be used for definitive identification. This uniqueness can be attributed to variations in morphology, size and different treatment history of every individual. Teeth are a good source of data for postmortem studies as they are durable structures and are able to resist decomposition. For this reason, forensic odontology has become a promising field in recent times. Materials used to restore teeth have also shown durability in adverse conditions and increase the variations that can help in identification as restorations can be considered as unique features. The aim of this review article is to describe the various ways restorative materials can aid in identification of individuals.

Keywords: Dental records, Dental restoration, Forensic science, Victim identification

INTRODUCTION

A person will cease to speak after death but the dead body has multitudes to say about the nature of death. For situations where identification via direct visualisation is not possible, Interpol has suggested three methods that are accepted and based on solid science- Fingerprint matching, DNA analysis and dental comparison [1].

Often times a positive identification can be nailed by fingerprint matching or DNA analysis itself but when the body is mutilated, burned and damaged beyond recognition, these methods may fail and forensic odontology shines through because of the resistant nature of teeth [2]. Dental hard tissues can withstand most adverse conditions without significant loss of microstructure [3].

In 1970 Keiser-Nielsen S, defined forensic odontology as “a branch of forensic medicine which in the interest of justice, deals with the proper handling and examination of dental evidence along with the proper evaluation and presentation of the dental findings” [4]. Historical evidence of dental remains being used for identification have been recorded in the literature, for example, Agrippina, a Roman empress, used forensic dentistry to identify her rival’s head. In 49 AD she confirmed the death of Lollia Polina by the presence of her blackened front tooth [5]. In the Charity Bazaar fire in Paris of 1897, 30 bodies were identified with the help of well-maintained dental records. These records noted the amalgam and gold restorations, crowns and extractions the victim had undergone [6]. One dentist, Oscar Amoedo played a pivotal role in the identification process during this incident and later in 1898 authored a book titled “L’Art dentaire en médicine légale”. This book laid down the groundwork for methods and techniques of victim identification via dentition. Oscar Amoedo now, is known as the father of forensic odontology [7].

Since then, expertise of forensic odontologists have been sought out in many mass fatality accidents like terrorist attacks, tsunamis, earthquakes, train, road traffic accidents and commercial plane crashes [8,9].

Restorative dentistry deals with rehabilitation of tooth structure that was lost due to carious or non carious causes. Dental caries is one of the most prevalent diseases in the world, so the possibility of an individual receiving a filling or multiple fillings in their lifetime is quite high. Added to that, as a person undergoes multiple dental treatments through their life, the total of filled, missing and decayed teeth creates a combination that is unique to the person, making identification an easier task [10]. Thus, the role of restorative dentistry in forensic odontology cannot be underestimated.

REVIEW OF RESTORATIVE DENTISTRY AS AN AID FOR IDENTIFICATION

Identification by restorations is possible in the following ways-

1) Identification of Ethnicity of Individual

The type and techniques of restorative work undertaken in a country may vary widely as it depends on the affluence of the country and the level of dental training provided [9,11]. It may not be possible to pinpoint the exact country but the geographical region may be identified [11]. This was demonstrated by Pretty IA and Addy LD, where they discussed the dental findings in two cases. One body was identified as Russian and the other Chinese based on the peculiarities in the dental work [11].

2) Radiographs of Restorations

Comparison of ante-mortem and postmortem radiographs is the most common method of identification in forensic odontology [12]. According to Keiser-Nielsen S, restorations on the surfaces of teeth are the smallest unit to be considered while comparing radiographs [4]. Many studies [10,13-15] have been conducted to understand the appearance of restorations on an X-ray and evaluate the identification potential. It is seen that the radiographic images of fillings have the same morphology in the ante-mortem and postmortem radiograph, which is unique and it becomes an extraordinary feature [10]. An extraordinary feature is defined as one that doesn’t occur in more than 10% of the population, and in certain situations this one extraordinary feature is enough for making a positive identification [10].

Phillips VM and Stuhlinger M, found that the appearance of a compound amalgam restoration on the radiographs is unique and acts as an extraordinary feature [13]. Borrman H and Gröndahl HG, concluded when amalgam restorations are present, matching two bitewing radiographs becomes an easier task [14].

With the increasing demands in aesthetics, composites are a popular choice for restorations. Composites contain heavy metals that impart radiopacity. Zondag H and Phillips VM [10] and Hemasathya BA and Balagopal S [15], concluded in their respective studies that radiographic appearance of composite restorations is unique and can act as conclusive identifiers.

Certain facts that need to be kept in mind are that restorations may fracture depending on the conditions of death, so achieving a radiographic match in such a situation may be difficult [15]. Also, it is impertinent to mimic the angulation of the ante-mortem radiographs as close as possible because distortions occur with increasing angulation which also challenges the identification process [13].

3) Identification of Incinerated Remains

Identification of charred remains of victims is challenging as extreme damage makes DNA analysis and fingerprint matching difficult. Dental comparison by radiography is also not possible if damage to the jaws has altered the structural relation of the dentition. Studies by Robinson FG et al., [16] and Carr RF et al., [17] demonstrate that even if high temperatures cause teeth to shrink and fragment, dental restorations are mostly able to withstand these high temperatures [18].

Pol CA and Gosavi SR, studied the incinerated remains of healthy, restored and unrestored teeth under Scanning Electron Microscope (SEM) and found that the restorative materials could be identified under SEM even after burning [19].

Patidar KA et al., also conducted a similar study where they checked the resistance of restorative materials to various high temperatures and the changes they underwent. The restorative materials used in the study were zinc phosphate cement, glass ionomer cement, amalgam, nickel-chromium metal crown and ceramic crown. The results of the study showed that even if the materials had undergone disintegration and loss of structural integrity, it was still possible to identify the materials even after heating them to 1100°C for 15 minutes [20].

Polilight™ is a portable light source used during forensic investigations to detect blood stains, latent finger-prints and bite marks. Carson DO et al., also evaluated the effectiveness of Polilight™ to detect tooth-coloured restorations where one group was undamaged and the other group was subjected to heat damage. Glass ionomers showed differentiating optical properties at wavelengths between 415-555 nm. Composite detection was enhanced at wavelengths around 415-530nm while wavelengths above 590nm were not of diagnostic value. After simulated incineration of teeth, they found that composites were still detectable under 350nm but glass ionomers lost their optical properties [21].

The responses of different restorations to high temperature exposures can be summarised as-

a) **Amalgam:** As the temperature rises, surface roughness increases significantly. Discontinuity of the margins at the tooth-restoration interface occurs due to mercury evaporation [22]. Vapours of mercuric oxides may produce golden threads on the cusps [23]. Silver, spherical globules are seen on the surface. These globules are said to arise due to separation of the phases of alloys [22]. Gunther H and Schmidt O referred to these globules as 'silver bullets'[24]. Some studies have reported pink pigments on the surface of amalgam restorations due to evaporation of copper oxides [25] which have been absent in other studies [26]. This can be explained by the difference in the alloy composition of different types of dental amalgam [26].

b) **Glass Ionomer Cements (GIC):** Glass ionomer restorations showed cracks, fractures, shrinkage and drastic decrease in compressive strength which could be because of loss of water from the matrix [27]. These restorations also showed a pink-red florescence under violet light (405nm) because of the presence of strontium. Strontium is specific to the glass ionomers produced by GC corporation. This characteristic presentation is valuable for identification [28].

c) **Composite resins:** Contraction was observed which can be explained by the evaporation of organic matrix [28]. Loss of organic matrix caused concentration of the inorganic matrix, which resulted in increase in microhardness. Also, heat exposure increased the polymerisation of the composite, leading to enhancement of its mechanical properties [29].

d) **Zinc phosphate:** Linings of zinc phosphate under amalgam were able to resist temperature changes very well and were found intact in the cavity even if the above lying amalgam restoration was dislodged [26].

e) **Indirect restorations:** Gold inlays have a layer of mercury vapour deposited on them, similar to amalgam fillings [26]. Nickel-chromium and metal ceramic crowns only show slight change in morphology but are mostly able to withstand high temperatures as porcelains are materials with very high heat resistance [20]. Metal ceramic crowns show pitting of the surface with exposure of the underlying metal at temperatures above 800°C [30].

4) Identification of Restorations Exposed to Cold Temperatures

Biancalana RC et al., studied the effect of cold temperatures on knoop hardness and surface roughness of restorative materials to help identification of victims of freezing. But no significant changes were seen in the surface properties of restorations at 2.5°C, -20°C, and -80°C [29].

5) Estimation of Time of Death in Drowning Situations

Determination of time of death is challenging in situations where the victim has drowned. In 2020, Salema CFBA et al., had undertaken a study to understand the changes that occurred in mechanical properties (Knoop hardness and surface roughness) of dental materials postimmersion in a marine environment. The aim was to determine if these changes could help in accurately estimating the time of death in drowning cases. The results showed a significant reduction in knoop microhardness and a significant increase in the surface roughness of the composite, glass ionomer cement and amalgam restorations that was directly related to the duration of immersion [31].

6) Identification of Amalgam Restorations

Dostalova T et al., reported a case where a positive identification was made by chemical analysis of amalgam restorations. Chemical analysis was done using CamScan 2 SEM with EDAX 9900. EDAX 9900 analyses the characteristic radiation of elements. The absence of zinc in the filling material confirmed the investigators, suspicion of the amalgam restoration being SAFARGAM produced by Safina company in Czech Republic [32].

7) Identification of Composite Restorations

Direct visual identification of composite restorations are not easy as they are tooth coloured and blend well with the adjacent tooth colour. The inorganic, organic and heavy metal fillers present in the composition of composites impart certain properties that make them exhibit properties different from the natural tooth structure. These properties help in identification. The following methods are described for identification of presence of composite restorations.

i. **Computed Tomography (CT) analysis-** Sakuma A et al., aimed to identify composite restorations using a three-dimensional CT analysis and recorded that composite was distinguished from the natural tooth because of the difference in Hounsfield Units (HU) [33].

ii. **Fluorescence-aided identification technique (FIT)-** Fluorescence is simply defined as emission of a longer wavelength of light when an object is illuminated with a shorter wavelength of light [34].

The ease of identification using FIT was studied by Meller C and Klein C, and they found that composite restorations could easily be identified and this method was easy to use, non invasive, less time-consuming and reproducible as well [34].

Other studies have demonstrated that best detection of composite restorations by fluorescence occurred at a wavelength of 400±5 nm [34].

Accuracy of identification of composites with FIT has also been proven recently in another study that used a fluorescence inducing device called SiroInspect (Dentsply Sirona, York, Pennsylvania, USA) with a spectral bandwidth of 397-411 nm and a peak wavelength of 404 nm [35].

iii. **Identification using ultraviolet light emitting diode flashlight-** Fluorescence of composites when exposed to Ultraviolet (UV) light is a well-documented phenomenon [36,37]. In 1985, Clark DH and Ruddick RF used long wave UV radiation to identify composite restorations and observed that 22 out of 27 of the restorations were easily identified [36]. Clark DH and Meeks DR, also compared UV radiation with Infra-Red (IR) radiation and concluded that UV radiation is better than near IR wavelengths for identification of composite restorations [37].

In the late 1990s the development of ultraviolet light emitting diodes (UV LED) led to the conception of UV LED flashlights. The Inova X5 UV LED flashlight was one such light developed for use in forensic investigations. It was small, inexpensive, lightweight, battery operated, and user-friendly [38]. Guzy G and Clayton MA, used this flashlight for identification of composite restorations in two cases with unidentified dental remains and concluded that this flashlight was effective in identifying composite restoration in human dental remains [38].

iv. **Identification methods relying on the physical properties of composites-**

a) **Identification using surface roughness difference-** Prinz JF replaced the bell of a stethoscope with a conventional dental probe. The surface roughness difference between composite restoration and tooth structure produced a sound difference between the two, that was recorded by the examiners using the modified stethoscope. The results revealed that three examiners identified all the restorations but two examiners missed one restoration each. Advantages of this technique was that equipment used was inexpensive, easily available, easily fabricated and did not require an electrical supply but this technique depended on a keen hearing [39].

b) **Identification using electrical conductivity difference-** Electrical conductivity of composite is 30 Mohm/cm while that of fresh enamel is 10 Mohm/cm and this difference can be measured on an ohm-metre. In this method two probes were used- one was attached to a voltage-controlled oscillator and the other was connected to a loudspeaker. Upon contacting a composite restoration, a change in frequency occurred. This frequency change was recorded and the conclusion derived was that composite could be differentiated from enamel. The major disadvantage of this method is that it can only be used on fresh samples as incinerated enamel has electrical conductivity about 30 Mohm/cm that cannot be differentiated [39].

v. **Identification of composite by brand-** Studies have demonstrated that dental resins not only retain the ability to be identified even after incineration but also can be identified by brand name. This feature increases the evidence for a positive identification and the value of such information is demonstrated in the case where the victim was identified from the incinerated remains of the tooth that was restored with an amalgam restoration bonded into place by a new resin cement. The cement contained zirconium and silicon, which was concurrent with Rely X ARC, produced by 3M ESPE. This was testified by the victim's dentist which led to the conviction of the suspect [18,40].

a) **Identification of composite brand with SEM/EDS and XRF-** Composite resins contain inorganic elements like strontium, barium, zirconium, and ytterbium that are added in different ratios by various brands and these elements maintain their structure post incineration. Hence, the presence of these inorganic elements aid in the forensic investigation process and make brand-wise identification possible. SEM with Energy Dispersive X-ray Spectroscopy (SEM/EDS) and X-ray fluorescence (XRF) are methods suggested for analysis of the inorganic elements present in composites [41].

The SEM/EDS is a reproducible and reliable technique that produces high resolution images of the product along with an X-ray spectrum that represents the elemental fingerprint of that product. Recognition of brands of composites are possible by this technique, even if the composite is burned. Elemental analysis by SEM/EDS technique uses an electron beam. Samples are placed in a vacuum chamber for analysis [41,42].

The X-ray Fluorescence (XRF) is another method to identify composite resins. It is similar to SEM/EDS but in this method the elemental analysis is done by X-rays. XRF analysis has an added advantage of being able to detect major, minor, and trace elemental levels while SEM/EDS can only detect major and minor elements. This is useful for identification of elements like strontium as strontium is added in resins in trace quantities ranging from 176-3700 parts per million (ppm). Other advantages are time efficiency, ease of analysis and portability of equipment, thus allowing on-site analysis of the samples. The samples do not need to be placed in a vacuum chamber [41].

Major disadvantage of XRF is that it cannot detect silicon because of its inability to detect below phosphorus in the periodic table as the low energy X-rays get absorbed in the air and cannot be analysed. This does not cause much issue as silicon is present in most brands of commercially available composites but composites which use silicon as the primary filler cannot be identified. In such cases, presence of silicon can be easily detected by SEM/EDS as the analysis is done in a vacuum chamber [41].

Spectral Library Identification and Classification Explorer (SLICE) software was developed with the Federal Bureau of Investigation (FBI) that stores the SEM/EDS and XRF data of the restorative resins. It efficiently archives the spectra and images of the resins and also allows for comparison of unknown material with that information already stored in the database [41].

Bush MA et al., did an extensive study on the SEM/EDS and XRF spectra of various composite brands before and after incineration to determine if they retained sufficient characteristics to be differentiated from one another. The conclusion of the study was that the resins retained their characteristics inspite of incineration and could easily be compared and recognised in the database [18,41,42].

Clinically, however, it is frequently seen that a single restoration is composed of two or more materials. Like, in sandwich technique, composite is placed above a layer of Glass Ionomer Cement (GIC). This layering of materials is done to optimise the advantages of and overcome the drawbacks of certain materials [43].

Thus, another study was undertaken by Soon AS et al., that aimed to explore the discernability of complex layered restorations in burnt teeth according to the individual materials used. Findings revealed that it was visually possible to distinguish the complex restoration from the incinerated tooth but individual materials could not be differentiated. Separate identification of each material was possible using SEM/EDS with secondary electron imaging and Backscattered Electron Imaging (BEI). Secondary electron imaging provided microstructural information of the material. BEI produced an image with a contrast directly proportional to the average atomic number i.e., a brighter contrast image was seen in elements with a higher atomic number. Secondary electron imaging and BEI made identification of Tetric EvoCeram (Ivoclar Vivadent, Amherst, NY, USA) and GC Fuji IX GP (GC Corporation, Tokyo, Japan) possible. While differentiation of various viscosities of the same material was possible with this method, it was observed that distinguishing the same brand of material in a different shade was not possible [43].

8) Identification of Restorations after Acid Attack

Concentrated acids are used to destroy bodies to prevent identification. Dental restorations are said to be more resistant to the action of acids than enamel, dentin, and cementum. Recently, the appearance of high copper dental amalgam, GIC and composite resin was studied after immersion in 75% sulphuric acid. The results depicted that high copper amalgam and composite resin showed a significant resistance to acid attack while GIC, showed a large loss of volume after exposure to sulphuric acid. Another parameter included was the use of Cone Beam Computed Tomography (CBCT) and an Artificial Intelligence (AI) algorithm to perform Three-Dimensional (3-D) reconstruction of dental tissues. These 3-D images were successfully matched with Two-Dimensional (2-D) dental records like Orthopantomograms (OPG) and Intraoral Periapical Radiographs (IOPA). The results of this study demonstrated successful integration of newer technologies for the detection of restorations in the discipline of forensic odontology [44].

DISCUSSION

As stated by Keiser-Nielsen S, every physical characteristic has some discriminatory potential depending on how frequently it occurs [45].

Teeth and restorations are considered as good evidence because they are the most stable structures in a human body, do not decompose, resist action of fungus and bacteria and can survive most harsh conditions [46,47]. When the skeletal and soft tissues have undergone severe damage, techniques described in forensic odontology have proven their value to yield reliable results [47]. Even a single tooth retrieved from a crime scene may be the only available evidence for identification of bodies and can provide valuable clues when no other evidence has been found [15]. Hence, forensic odontology has become an indispensable speciality when it comes to identification of the unknown.

Steps should be taken to promote forensic odontology because forensic odontologists are becoming increasingly important in disaster victim identification and other medico-legal situations. Dentists with experience of working in such cases must be encouraged to join investigation teams and educate dental graduates about this specialisation. This can help to distinguish forensic odontology as a distinct field within forensic science [9].

Most commonly used technique in forensic odontology is comparison of ante-mortem and postmortem data. The data is usually available as case papers, charts, photographs, models, and radiographs [15]. For this reason, correct recording and charting of restorations is necessary as presence of a restoration in ante-mortem records but absence of the same restoration in postmortem records is an inconsistency that can lead to exclusion of identity [48].

Dental clinicians and specialists can help forensic procedures by making it mandatory in their practices to note dental anomalies such as odd number and uncommon presentations of root canal anatomy, bony landmarks, pulp stones, localised hypercementosis etc [9,49]. If there are observations on unusual relationship of maxillary sinus to maxillary molars or of mandibular canal to mandibular molars, these can be diligently noted as part of patient records [9]. Any information that can be made available on the restorations can make the investigation proceed smoothly, hence dentists are encouraged to maintain legible records for long periods of time along with inclusion of brand names of the restorative materials used for their patients [49,50].

Odontologic material that is collected postmortem for use as evidence in forensic analysis needs to be preserved in a manner that conforms to requirements of law enforcement agencies and judicial bodies [9]. There is an extant need for standardisation in methods for collection and preservation of potential odontologic evidence [9]. With a thorough knowledge of restorative materials and proper documentation, specialists in conservative dentistry and endodontics can help in forensic identification [48].

More research that aims at exploring the role of restorative dentistry in forensic identification should be encouraged and published. These publications will ensure greater access to the public and simultaneously help other branches, like the police, judiciary and forensic medicine teams, who are associated with the identification process, to better understand the importance of the evidence obtained from our speciality [48]. As it has been rightly said, every contact leaves a trace- so with the right attitude, knowledge, team work and resources, identification in forensics becomes an achievable possibility [51].

CONCLUSION(S)

The techniques mentioned in this article have been adopted by forensic odontologists around the world to aid in identification of restorations as it may be the much-needed crucial evidence to ensure a positive identification. Forensic odontology has marked its importance in the identification of unknown when other forensic tools have failed. Restorative dentistry plays a key role in this process. Dentists should understand the responsibility and widen their knowledge to find evidence from odontogenic traces. Practitioners must be encouraged to keep detailed records and cooperate with investigating authorities to accomplish this challenging task.

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REFERENCES

[1] DVI guide [Internet]. [Updated 2009; cited 2018 Dec 14]; Available from: http://www.interpol.int/INTERPOLexpertise/Forensics/DVI-Pages/DVI-guide.
[2] Rothwell BR. Principles of dental identification. Dent Clin North Am. 2001;45(2):253-70. PMID: 11370454.
[3] Karthika B, Elumalai M. Identity of blood group from dental pulp of deceased human. Int J Pharma Bio Sci. 2013;4:1000-04.
[4] Keiser-Nielsen S. Person Identification by Means of Teeth. Bristol: John Wright and Sons. 1980.
[5] Dio C, Earnest C, Baldwin HF. Dio's Roman History. London. W. Hememamm. 1914.
[6] Bruce-Chwatt RM. A brief history of forensic odontology since 1775. J Forensic Leg Med. 2010;17(3):127-30. Doi: 10.1016/j.jflm.2009.12.007. PMID: 20211451.
[7] Amedo O. The role of dentist in the identification of the victims of the catastrophe of the "Bazar de la Charite. Paris, Dental Cosm. 1987;39:905-12.
[8] Prajapati G, Sarode SC, Sarode GS, Shelke P, Awan KH, Patil S, et al. Role of forensic odontology in the identification of victims of major mass disasters across the world: A systematic review. PLoS One. 2018;13(6):e0199791. Doi: 10.1371/journal.pone.0199791. PMID: 29953497.
[9] Krishnan K, Kanchan T, Garg AK. Dental evidence in forensic identification-An overview, methodology and present status. Open Dent J. 2015;9:250-56. Doi: 10.2174/1874210601509010250. PMID: 26312096.
[10] Zondag H, Phillips VM. The discrimination potential of radio-opaque composite restorations for identification: Part 3. J Forensic Odontostomatol. 2009;27(1):27-32. PMID: 22717956.
[11] Pretty IA, Addy LD. Associated postmortem dental findings as an aid to personal identification. Sci Justice. 2002;42(2):65-74. Doi: 10.1016/S1355-0306(02)71801-7. PMID: 12407975.
[12] Ranganathan K, Thavarajah R, Lakshminarayanan V. Forensic odontology: A review. J Forensic Odontol. 2008;1:04-12.

[13] Phillips VM, Stuhlinger M. The discrimination potential of amalgam restorations for identification: Part 1. J Forensic Odontostomatol. 2009;27(1):17-22. PMID: 22717954.
[14] Borrman H, Gröndahl HG. Accuracy in establishing identity by means of intraoral radiographs. J Forensic Odontostomatol. 1990;8(2):31-36. PMID: 2130048.
[15] Hemasathya BA, Balagopal S. A study of composite restorations as a tool in forensic identification. J Forensic Dent Sci. 2013;5:35-41. Doi: 10.4103/0975-1475.114561.
[16] Robinson FG, Rueggeberg FA, Lockwood PE. Thermal stability of direct dental esthetic restorative materials at elevated temperatures. J Forensic Sci. 1998;43(6):1163-67. PMID: 9846393.
[17] Carr RF, Barsley RE, Davenport WD. Postmortem examination of incinerated teeth with the scanning electron microscope. J Forensic Sci. 1986;31(1):307-11. PMID: 3944572.
[18] Bush MA, Bush PJ, Miller RG. Detection and classification of composite resins in incinerated teeth for forensic purposes. J Forensic Sci. 2006;51(3):636-42. Doi: 10.1111/j.1556-4029.2006.00121.x. PMID: 16696713.
[19] Pol CA, Gosavi SR. Scanning electron microscopic analysis of incinerated teeth: An aid to forensic identification. J Oral Maxillofac Pathol. 2014;18(1):32-35. Doi: 10.4103/0973-029X.131889 PMID: 24959034.
[20] Patidar KA, Parwani R, Wanjari S. Effects of high temperature on different restorations in forensic identification: Dental samples and mandible. J Forensic Dent Sci. 2010;2(1):37-43. Doi: 10.4103/0974-2948.71056. PMID: 21189989.
[21] Carson DO, Orihara Y, Sorbie JL, Pounder DJ. Detection of white restorative dental materials using an alternative light source. Forensic Sci Int. 1997;88(2):163-68. Doi: 10.1016/s0379-0738(97)00115-1. PMID: 9251235.
[22] Vandrangi SK, Radhika MB, Paremala K, Reshma V, Sudhakara M, Hosthor SS, et al. Adjunctive role of dental restorations in personal identification of burnt victims. J Oral Maxillofac Pathol. 2016;20(1):154-61. Doi: 10.4103/0973-029X.180981. PMID: 27194881.
[23] Moreno S, Merlati G, Marin L, Savio C, Moreno F. Effects of high temperatures on different dental restorative systems: Experimental study to aid identification processes. J Forensic Dent Sci. 2009;1(1):17-23. Doi: 10.4103/0974-2948.50883.
[24] Gunther H, Schmidt O. Die Zerstorung des menschlichen Gebisses im Verlaufe der Einwirkung hoher Temperaturen. Dtsch Z Ges Gerichtl Med. 1953;42:180-88.
[25] Merlati G, Savio C, Danesino P, Fassina G, Menghini P. Further study of restored and unrestored teeth subjected to high temperatures. J Forensic Odontostomatol. 2004;22:17-24.
[26] Bagdey SP, Moharil RB, Dive AM, Thakur S, Bodhade A, Dhobley AA, et al. Effect of various temperatures on restored and unrestored teeth: A forensic study. J Forensic Dent Sci. 2014;6(1):62-66. Doi: 10.4103/0975-1475.127777. PMID: 24696591.
[27] Biancalana RC, Vicente SA, Alves da Silva RH, Pires-de-Souza FC. Color stability of dental restorative materials submitted to heat sources, for forensic purposes. J Forensic Sci. 2017;62(2):355-60. Doi: 10.1111/1556-4029.13292. PMID: 27864970.
[28] Kiran R, Chapman J, Tennant M, Forrest A, Walsh LJ. Effect of heat on the fluorescence properties of tooth-colored restorative materials and their forensic implications. J Forensic Sci. 2019;64(6):1698-06. Doi: 10.1111/1556-4029.14122. PMID: 31674673.
[29] Biancalana RC, Vincenti SAdF, da Silva RHA, Pires-de-Souza FCP. Analysis of the surface roughness and microhardness of dental restorative materials exposed to heat sources and cold temperatures for human identification purposes. Egypt J Forensic Sci. 2019;9(8):1-9. Doi:10.1186/s41935-019-0114-x.
[30] Sharma S. Macroscopic and microscopic effects of elevated temperatures on unrestored and restored teeth: An in-vitro forensic study. Asian J Med Sci. 2020;11(2):75-78. Doi: 10.3126/ajms.v11i2.26364.
[31] Salema CFBA, Silva PGB, Oliveira PMDC, Sousa FB, Silva RHAD, Silva LVD, et al. Forensic study of mechanical properties of dental fillings after immersion in marine environment. Forensic Sci Int. 2020;313:110362. Doi: 10.1016/j.forsciint.2020.110362. PMID: 32593111.
[32] Dostalova T, Eliasova H, Seydlova M, Broucek J, Vavrickova L. The application of CamScan 2 in forensic dentistry. J Forensic Leg Med. 2012;19(7):373-80. Doi: 10.1016/j.jflm.2012.04.015. PMID: 22920758.
[33] Sakuma A, Saitoh H, Makino Y, Inokuchi G, Hayakawa M, Yajima D, et al. Three-dimensional visualization of composite fillings for dental identification using CT images. Dento Maxillo Facial Rad. 2012;41(6):515-19. Doi: 10.1259/dmfr/13441277. PMID: 22868297.
[34] Meller C, Klein C. Fluorescence properties of commercial composite resin restorative materials in dentistry. Dent Mater J. 2012;1:31:91 Doi: 10.4012/dmj.2012-079. PMID: 23207195.
[35] Auderset FC, Connert T, Meller C, Filippi A, Dagassan-Berndt DC. Evaluation of five methods to identify composite restorations in human teeth on a forensic purpose—an ex vivo comparative study. Int J Legal Med. 2022:01-12. Doi: 10.1007/s00414-022-02869-z. PMID: 35945461.
[36] Clark DH, Ruddick RF. Post mortem detection of tooth-coloured dental restorations by ultra violet radiation. Acta Med Leg Soc (Liege). 1985;35(1):278-84. PMID: 2979892.
[37] Clark DH, Meeks DR. A preliminary investigation of ultraviolet and near infrared wavelengths in the postmortem detection of composite dental restorative materials. Can Soc Forensic Sci J. 1989;22(2):219-24. Doi: 10.1080/00085030.1989.10757435.
[38] Guzy G, Clayton MA. Detection of composite resin restorations using an ultraviolet light-emitting diode flashlight during forensic dental identification. Am J Forensic Med Pathol. 2013;34(2):86-89. Doi: 10.1097/PAF.0b013e3182886f77. PMID: 23574870.
[39] Prinz JF. A modified stethoscope to assist in the identification of tooth-coloured restorations. Med Sci Law. 1994;34(1):51-53. Doi: 10.1177/002580249403400107. PMID: 8159072.
[40] State of Minnesota v. Donald Blom, 682 N.W. 2d 578.
[41] Bush MA, Miller RG, Norrlander AL, Bush PJ. Analytical survey of restorative resins by SEM/EDS and XRF: Databases for forensic purposes. J Forensic Sci. 2008;53(2):419-25. Doi: 10.1111/j.1556-4029.2007.00654.x. PMID: 18298491.
[42] Bush MA, Miller RG, Prutsman-Pfeiffer J, Bush PJ. Identification through XRF analysis of dental restorative resin materials: A comprehensive study of non-cremated, cremated, and processed cremated individuals. J Forensic Sci 2007;52(1):157-65. Doi: 10.1111/j.1556-4029.2006.00308.x. PMID: 17209929.
[43] Soon AS, Bush MA, Bush PJ. Complex layered dental restorations: Are they recognizable and do they survive extreme conditions? Forensic Sci Int. 2015;254:01-04. Doi: 10.1016/j.forsciint.2015.06.016. PMID: 26151675.
[44] Thurzo A, Jančovičová V, Hain M, Thurzo M, Novák B, Kosnáčová H, et al. Human remains identification using micro-CT, chemometric and AI methods in forensic experimental reconstruction of dental patterns after concentrated sulphuric acid significant impact. Molecules. 2022;27(13):4035. Doi: 10.3390/molecules27134035. PMID: 35807281.
[45] Keiser-Nielsen S. Dental identification: Certainty V probability. Forensic Sci 1977;9(2):87-97. Doi: 10.1016/0300-9432(77)90073-5. PMID: 852792.
[46] Divakar KP. Forensic odontology: The new dimension in dental analysis. Int J Biomed Sci. 2017;13(1):01-05. PMID: 28533730.
[47] Mörnstad H, Pfeiffer H, Yoon C, Teivens A. Demonstration and semi-quantification of mtDNA from human dentin and its relation to age. Int J Legal Med. 1999;112:98-100. Doi: 10.1007/s004140050209. PMID: 10048666.
[48] Balagopal S. The application and cogency of dental restorations and endodontics in forensic odontology. J Oper Dent Endod. 2021; 6 (2):51-52. Doi: 10.5005/jp-journals-10047-0117.
[49] Silva RF, Franco A, Picoli FF, Nunes FG, Estrela C. Dental identification through endodontic radiographic records: A case report. Acta Stomatol Croat. 2014;48(2):147-50. PMID: 27688359.
[50] Bonavilla JD, Bush MA, Bush PJ, Pantera EA. Identification of incinerated root canal filling materials after exposure to high heat incineration. J Forensic Sci 2008;53(2):412-18. Doi: 10.1111/j.1556-4029.2007.00653.x. PMID: 18298492.
[51] Sumalatha S, Padmaja S, Thumati P. Every contact leaves its trace– insight into recent advances of forensic odontology. J Cancer Treat Res. 2015;3(1):01-07. Doi: 10.11648/j.jctr.20150301.11.

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