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Role Of Lasers In Forensic Odontology From A Prosthodontic Point Of View- A Literature Review

Authors:

Dr. Kanchan Mokashi[1]

Dr. Prasad Adhapure[2]

Dr. Sakshi Suryawanshi[3]

Dr. Ashwini Kuche[4]

Dr. Sahil Dahale[5]

1) MDS student, Department of Prosthodontics, Chhatrapati Shahu Maharaj Shikshan Sanstha's Dental College and Hospital, Kanchanwadi, Chhatrapati Sambhajinagar, Maharashtra.
2) MDS, Professor and PG Guide, Department of Prosthodontics, Chhatrapati Shahu Maharaj Shikshan Sanstha's Dental College and Hospital, Kanchanwadi, Chhatrapati Sambhajinagar, Maharashtra.
3) MDS student, Department of Prosthodontics , Chhatrapati Shahu Maharaj Shikshan Sanstha's Dental College and Hospital, Kanchanwadi, Chhatrapati Sambhajinagar, Maharashtra.
4) MDS student, Department of Prosthodontics, Chhatrapati Shahu Maharaj Shikshan Sanstha's Dental College and Hospital, Kanchanwadi, Chhatrapati Sambhajinagar, Maharashtra.
5) MDS student, Department of Prosthodontics, Chhatrapati Shahu Maharaj Shikshan Sanstha's Dental College and Hospital, Kanchanwadi, Chhatrapati Sambhajinagar, Maharashtra.

ABSTRACT-

Forensic dentistry is crucial for identifying deceased individuals when visual or other identification methods are not feasible, especially after mass disasters or criminal activities. Accurate and timely identification of the deceased and injured is essential in the aftermath of any disaster. Establishing a person's identity often relies on common methods such as dental, DNA, and fingerprint analyses. Forensic odontology, a specialized branch of dentistry, plays a significant role in identifying individuals involved in accidents, civil unrest, natural and mass disasters, and crimes related to genocide. When natural teeth are absent, marking or labelling dentures becomes vital for personal identification. Incorporating a paper or embossing patient data on dentures can be difficult to read due to the opacity of the acrylic resin. Therefore, using a laser for auto-identification is especially beneficial as it is cost-effective, time-efficient, and less cumbersome.

INTRODUCTION-

For a long time, national and international security have been top priorities for ensuring the safety and protection of people's assets. Both crime prevention and detection techniques are emphasized in national security efforts. Forensic science is crucial in this context, encompassing a wide range of scientific and technological disciplines that aid in the effective detection and prevention of crime. For example, forensic pathology examines body tissues and fluids, toxicology studies poisons (including drugs), odontology analyses the teeth of deceased individuals, and anthropology studies human beings. Fundamental disciplines such as biology, chemistry, and physics are integral to forensic science.[1]

The invention of lasers in 1958 and their subsequent advancements over the past decade have revolutionized many scientific and technological fields, including forensic science.[1]

The versatility of lasers has led to their widespread adoption across diverse fields, including medicine, manufacturing, communications, research, and entertainment. Originally conceived as a solution in search of a problem, lasers now perform a multitude of tasks, from drilling holes in durable materials to treating medical conditions and enhancing communication systems.[2]

Lasers are now extensively used in areas like laser-induced fluorescence for detecting latent fingerprints, laser ablation of minute samples, laser scanning microscopy, laser-assisted DNA sequencing, 3D imaging, and portable lasers for discovering and retrieving trace evidence at crime scenes. This is an ever-evolving field, with continuous improvements in laser technology and forensic detection methods.[1]

ROLE OF A FORENSIC DENTIST-

The forensic dentist plays a crucial role in identifying deceased individuals through dental identification, which involves two main steps. The first and most common step is a comparative identification, where the remains of a decedent are compared to ante mortem (before death) records to establish a high degree of certainty. Information from the body or circumstantial evidence typically aids in identifying the deceased. The second step is used when ante mortem records are unavailable and there are no clues to the individual's possible identity. In such cases, the forensic dentist creates a post-mortem (after death) dental profile that suggests characteristics of the individual, helping to narrow the search for ante mortem materials.[3]

Identifying deceased individuals serves various purposes:
1. Criminal: Criminal investigations often cannot proceed until the victim has been positively identified.
2. Marriage: In many religious traditions, individuals cannot remarry unless their partners are confirmed deceased.
3. Monetary: Payments for pensions, life insurance, and other benefits require positive confirmation of death.
4. Burial: Many religions require positive identification before burial in specific geographic sites.
5. Social: Society has a duty to preserve human rights and dignity beyond life, starting with establishing an individual's identity.
6. Closure: Identifying individuals who have been missing for long periods can bring sorrowful relief to their families.[3]

Dental identifications are especially important in natural and manmade disaster situations, particularly in mass casualty events like aviation disasters. Given the lack of a comprehensive fingerprint database, dental identification is becoming an increasingly essential part of forensic investigation.[3]

ROLE OF A PROSTHODONTIST-

Forensic identification using prosthodontic appliances, such as denture marking and barcoding, is gaining significance by providing vital clues for identifying individuals. The primary roles of prosthodontists in forensic odontology include:

1. Sound Knowledge of Dental Materials: Prosthodontists must have a thorough understanding of the materials used in dental appliances.
2. Engraving Records into Prostheses: They need to find effective ways to engrave identifying information onto dental prostheses.
3. Studying the Pattern of Rugae: This involves analysing the unique ridges on the roof of the mouth, which can help in identification.
4. Impression Making of Bite Marks: Creating accurate impressions of bite marks for comparison and analysis.
5. Lip Print Recording and Identification: Recording and analysing lip prints, which are unique to individuals, for identification purposes.[4]

These practices enhance the ability to identify individuals through their dental prostheses and associated records, playing a crucial role in forensic investigations.[4]

DENTURE MARKING-

Following major disasters such as earthquakes, fires, or floods, early and definitive identification (ID) of the dead and injured is crucial. Often, this ID must be accomplished through forensic dentistry. Determining various physical and genetic characteristics of human dentition has proven highly effective in aiding identification. However, edentulous individuals, who have lost all or most of their teeth, present a greater challenge unless they wear ID-marked dentures. These dentures generally remain undamaged due to the protection provided by the soft tissues of the oral cavity.

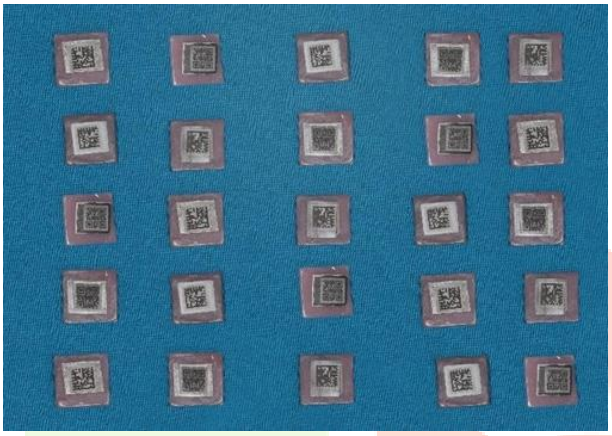
The frequency of edentulous-ness has decreased in recent years due to improvements in oral health, such as fluoridation and increased patient awareness. However, due to varying oral health status across different populations, denture identification remains essential, as identifying an edentulous person is more difficult than a dentate one. In the absence of marked dentures, identification may only be established by comparing bone trabeculation patterns in ante-mortem and post-mortem radiographs by well-trained examiners.

ID marks on dental prostheses serve two main functions. First, they facilitate the identification of the patient, useful in cases of unconsciousness, memory loss, or for forensic purposes. Second, identifying the denture of a living patient is beneficial for production laboratories and institutions such as hospitals and community homes. Dentures with identity marks have proven highly beneficial. Various denture marking systems have been reported in the literature, broadly divided into surface marking or engraving methods and inclusion methods. However, none fully meet all the requirements of the American Dental Association (ADA). The ideal requirements are:

1. The mark on the denture must yield a positive ID.
2. The marking technique must be easy, quick, and inexpensive to implement.
3. The mark should be fire-resistant, or if not, placed in a protected area, such as palatally or lingually in the molar region.
4. The marking method should not affect the durability of the denture base material.
5. The mark should be cosmetically acceptable and as unobtrusive as possible.[5]

LASER MICRO-ETCHING-

Laser micro-etching is a precise noncontact ablative denture marking technique that can be used for prostheses-guided personal identification. This method allows for precise marking on metal prostheses without compromising their integrity or aesthetics, making it a valuable tool for personal and forensic identification purposes.[6]



Samples with 2D and QR code laser etched on titanium chips.

QR code inserted in the denture.

Laser micro-etching is a precise noncontact ablative denture marking technique used for prostheses-guided personal identification. Here is an elaboration of the process of laser micro-etching:

1. Preparation: The process begins with the preparation of the metal intraoral prosthesis that requires marking. This may involve cleaning the surface to ensure it is free from any contaminants that could interfere with the etching process.
2. Laser Engraving Machine Setup: A laser engraving machine is used for the micro-etching process. The specific parameters for the laser, such as wavelength, power, frequency, and marking speed, are set based on the material of the prosthesis and the desired depth of the etching.
3. Character Input: The characters or markings to be etched onto the prosthesis are input into the software that controls the laser engraving machine. This allows for precise control over the design and content of the markings.
4. Focusing the Laser: The laser beam is focused on the surface of the prosthesis using the laser engraving machine. The focal point of the laser beam is small, typically ranging in fractions of millimetres, ensuring that only the targeted area is affected by the laser.
5. Etching Process: When the laser beam passes over the surface of the prosthesis, the energy delivered by the laser heats the surface under its focal point and vaporizes the focused point. This controlled vaporization creates the desired markings on the prosthesis.
6. Controlled Depth: The laser engraving machine is set to penetrate a fixed depth into the prosthesis, typically around 0.5 mm, to avoid unnecessary weakening of the prosthesis. This depth is crucial for ensuring the longevity and legibility of the markings.
7. Precision and Aesthetics: Laser micro-etching is a precise technique where the etching is not visible to the naked eye and requires magnification, such as a magnifying lens or microscope, for visualization. This results in aesthetically pleasing and discreet markings on the prosthesis.
8. Coverage and Preservation: The etching is typically performed in an area of the prosthesis that will be covered by acrylic resin, ensuring that the markings are preserved and protected. This helps maintain the integrity of the markings over time.
9. Limitations: While laser micro-etching is a precise and cost-effective technique, it may require adequate thickness of metal surfaces for etching and access to a laser engraving unit. However, it can be a reliable tool for personal identification on metallic prostheses.

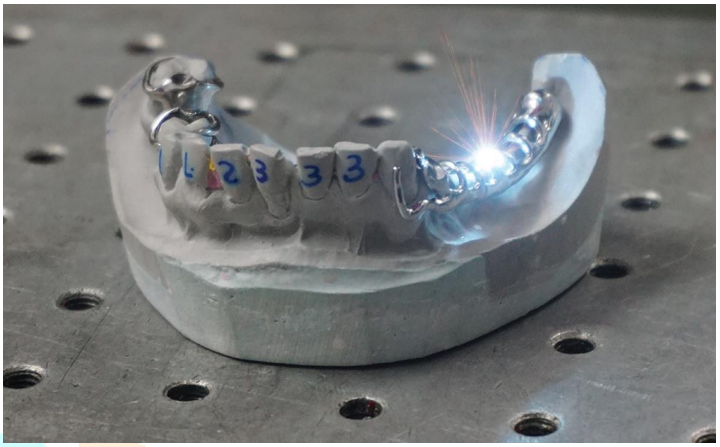
In conclusion, laser micro-etching is a sophisticated and effective method for marking metal intraoral prostheses, providing a permanent mode of personal identification with minimal impact on the prosthesis itself.[6]

DIODE LASER MICRO-ETCHING-

Diode laser micro-etching is a precise and non-contact ablative denture marking technique that can be used for personal identification on metal prostheses. Diode lasers, such as those with Nd :YAG crystals, are commonly used for laser engraving purposes due to their versatility and control features. These lasers emit light in the wavelength of 1064 nm and can be controlled by a computer to determine the intensity, direction, speed of movement, and beam spread. The laser beam heats the surface it is directed at under its focal point, vaporizing the focused point to create markings.

In the context of denture marking, diode laser micro-etching can provide a permanent mode of personal identification on metallic prostheses. This technique is cost-effective, precise, and offers good aesthetics as the etching is not visible to the naked eye and requires magnification for visualization. It is important to note that laser micro-etching requires specific equipment like the Kite Laser Machine and appropriate parameters for engraving, such as frequency, power, marking speed, and depth.

Overall, diode laser micro-etching is a valuable tool for marking metal prostheses for personal identification purposes, offering a reliable and efficient method for forensic and clinical applications.[6]



Laser micro-etching using diode laser

COPPER VAPOUR LASER-

A Copper Vapour Laser (CVL) is a type of gas laser that generates its laser light using a mixture of copper vapour and a buffer gas, typically neon. Here are some key points about Copper Vapour Lasers:

1. Operating Principle:
   - CVL operates on the principle of optical amplification based on the transition of copper atoms in a vapour state. When electric current passes through the copper vapor, it gets excited and emits laser light when it returns to its ground state.

2. Output Wavelengths:
   - CVL typically emits laser light at two main wavelengths: 511 nm (green) and 578 nm (yellow). These wavelengths are in the visible spectrum and are suitable for various applications.

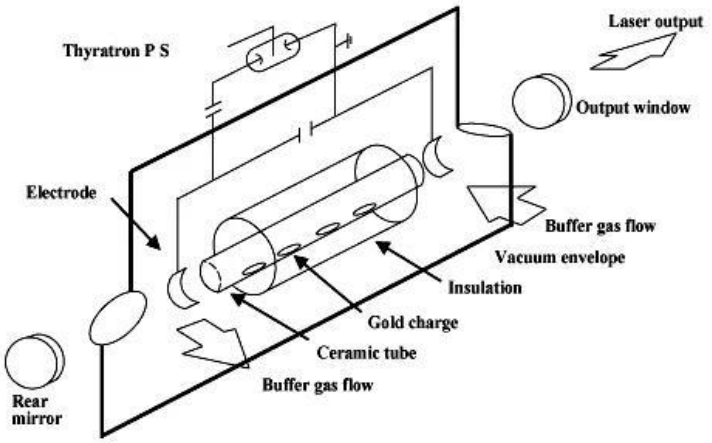
3. High Efficiency:
   - CVLs are known for their high efficiency in converting electrical energy into laser light. This efficiency contributes to their effectiveness in various laser applications.

4. Pulse Repetition Frequency:
   - CVLs can operate at high pulse repetition frequencies, typically in the range of 5 to 20 kHz. This high repetition rate allows for rapid and efficient laser output.

5. Peak Power:
   - CVLs can deliver high peak powers exceeding 50 kW, making them suitable for applications requiring intense laser energy in short pulses.

6. Applications:
   - CVLs are used in various applications such as material processing, laser marking, engraving, medical treatments, and scientific research due to their ability to produce high-quality laser beams with specific wavelengths.

In the context of denture marking, CVLs are utilized for engraving detailed information on metal components of dentures and restorations, providing a durable and precise method for identification purposes.



Copper Vapour Laser Schematic

ADVANTAGES OF COPPER VAPOUR LASER-

The advantages of using a copper vapour laser (CVL) for labelling cobalt-chromium components of dentures and metal restorations compared to other methods include:

1. Precision and Legibility: The CVL can produce very fine markings of a few microns width, enabling detailed information to be stored on metal surfaces with high precision and legibility.
2. Durability: Labelling with a CVL on cobalt-chromium components provides durability, making the markings resistant to damage or destruction, especially in situations like fires.
3. Adjustable Printing Size: The size of the printing with a CVL can be adjusted, allowing for markings to be made at varying sizes, including down to microscopic levels, to incorporate extensive personal particulars for identification purposes.
4. Efficiency: The CVL delivers high peak power with plasma ablation of the alloy surface, resulting in efficient and clear engravings on metal surfaces.
5. Effectiveness: While the initial setup cost of a CVL may be high, the cost of engraving is relatively low or negligible, making it a cost-effective solution for denture marking.
6. Customization: The CVL allows for the incorporation of detailed personal information such as the wearer's full name, gender, nationality, personal identification number, country of origin, and contact details, facilitating rapid and accurate identification.[7]

Overall, the use of a copper vapour laser for denture marking offers advantages in terms of precision, durability, efficiency, customization, and cost-effectiveness compared to traditional marking methods, making it a valuable tool for identification purposes in various scenarios.[7]

Labelling done with a copper vapour laser (CVL) on cobalt-chromium components of dentures and metal restorations is more durable and resistant to damage compared to labelling on acrylic resin components. Here's how it compares in terms of durability and legibility:

1. Durability:
- CVL Labelling on Metal Components: The markings produced by a CVL on metal surfaces, such as cobalt-chromium components, are highly durable and resistant to damage. They can withstand various environmental factors, including fire, making them suitable for long-term identification purposes.
- Labelling on Acrylic Resin Components: In contrast, labelling on acrylic resin components may be more susceptible to damage, especially in high-temperature environments like fires. Acrylic resin markings can easily be destroyed or altered, compromising the identification information.

2. Legibility:
- CVL Labelling on Metal Components: The CVL can create very fine markings with high precision and legibility on metal surfaces. The detailed information stored through CVL labelling remains clear and readable over time, ensuring accurate identification [T6].
- Labelling on Acrylic Resin Components: Labelling on acrylic resin components may not offer the same level of legibility and longevity as metal surfaces. The markings on acrylic resin can fade, wear off, or be damaged, leading to potential loss of identification information.

In summary, labelling with a CVL on metal components provides superior durability and legibility compared to labelling on acrylic resin components. The use of CVL for denture marking ensures that the identification information remains intact and easily readable, even in challenging conditions, making it a reliable method for long-term identification purposes.[7]

IDENTIFICATION OF DENTAL IMPLANTS THROUGH LASER ETCHING-

The physical properties of dental implants, such as high corrosion resistance, structural strength, and high melting point, contribute to their potential for identification. These properties allow implants to resist thermal insults, making them more likely to survive extreme conditions like incineration compared to other dental restorative materials. Additionally, the ability of implants to retain batch numbers even after exposure to high temperatures enhances their value as potential identifiers in forensic investigations.[8]

This has significant implications for forensic odontology and the identification of deceased individuals using dental implants. The research demonstrates that batch numbers within dental implants can survive high temperatures, providing a potential avenue for identification even after exposure to extreme conditions like incineration. By utilizing batch numbers or potentially individual serial numbers within implants, forensic investigators could enhance their ability to link implants to specific individuals, thereby aiding in the identification process. This approach could complement other identification methods, especially in cases where traditional identifiers like DNA or fingerprints are not available. Overall, the study suggests that dental implants, with their unique identification markers, have the potential to serve as valuable tools in forensic investigations involving human remains.

In conclusion, the study on the survival of batch numbers within dental implants following incineration highlights the potential of using these implants as identifiers in forensic odontology. The research shows that batch numbers can withstand high temperatures, with implants retaining identifiable markings even after exposure to intense heat. By considering the incorporation of individual serial numbers on implants, a new approach to identifying deceased individuals could be established. This study underscores the importance of

batch numbers within implants as a potential tool for forensic identification, offering a valuable resource for forensic odontologists and investigators in cases where traditional identifiers may be compromised.[8]

CONCLUSION-

The use of lasers in forensic dentistry has garnered interest for their application in Auto ID for complete dentures, particularly in the context of body identification following disasters. Initial efforts involved using barcodes printed on paper. Subsequently, auto ID data development progressed to laser-engraved matrix codes on instruments. This advancement led to the evaluation of matrix codes for identifying dental appliances, making the process less cumbersome and more cost-effective. Consequently, this technology aids forensic experts in timely and effectively identifying victims of mass disasters.[9]

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