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REVIEW ARTICLE

A Review on Denture Marking Systems: A Mark in Forensic Dentistry

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Abstract "Identification through forensic science is an art of giving the corpse a name A real life detective work that would put even Sherlock Homes to shame." Forensic dentistry deals with proper handling and examination of dental evidence and proper evaluation and presentation of dental findings in interest of justice. The Prosthodontists are playing a very important role in forensic dentistry as they are concerned with fabrication of various prosthesis which can serve as an important tool for identification. Identification is essential requirement of any medico-legal investigation because a wrong identity may pose a problem in delivering justice. This article describes the different methods for identification/marking of the complete dentures, removable partial dentures and fixed partial dentures and the importance of denture marking in forensic investigatory purposes. The PubMed, Ebsco and Google search engines were used to gather the articles.

Keywords Denture marking · Lenticular card · Medicolegal · Memory card · Surface marking · Inclusion method

Introduction

Forensic odontology, or forensic dentistry has been defined by Keiser-Neilson in the year 1970 as "that branch of forensic medicine which in the interest of justice deals with the proper handling and examination of dental evidence and with the proper evaluation and presentation of dental findings."

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Identification is an essential requirement of any medico-legal investigation because a wrong identity may pose a problem in delivering justice. The American Board of Forensic Odontology guidelines indicate that most dental identifications are based on restorations, caries, missing teeth and/or prosthetic devices. Prosthodontists play a very important role in forensic dentistry as they are concerned with fabrication of various prosthesis which can serve as an important tool for identification. Denture marking is accepted as a means of identifying dentures and persons in geriatric institutions or post mortem during war, crimes, and civil unrest, natural and mass disasters. The aim of this article is to review the different methods of denture marking and its importance in forensic investigatory purposes.

Review of Literature

Since ancient time dental prosthesis have been used to identify victims of natural and mass disasters.

Ancient

In 2500 BC the first dental evidence was found in pyramid at Giza-a skull with gold wire holding molar together.

In the year 66 AD, Nero's mistress Sabina got his wife killed by her soldiers and she recognized her body by two maxillary canines.

17th Century

First mention of dental forensics in American history was in 17th century. In 1776 Paul Revere [1] identified the body of General Joseph Warren by a missing maxillary canine tooth which was replaced by a piece of Walrus tusk as a pontic.

18th–19th Century

In 18th century, Cunningham [2] proposed denture marking as a tool for forensic identification and it was brought into focus by Dr. Robert H. Griffiths during his tenure as president of the American Dental Association.

In 1835 Turner et al. [1] reported that the Countess of Salisbury which was burnt to death was identified by her gold denture.

In 1850, incinerated bits of bone and a removable partial denture were retrieved and Dr. Keep [1] testified these were parts of denture which helped in identifying the dead body of Dr. Parkman. This contributed a great deal of circumstantial evidence and Dr. Keep was appointed as the first dean of Harvard Dental School.

20th Century

In 1976, Turner et al. [1] discussed the social advantage of marking dentures and reviewed the numerous systems and their relative merits.

In the year 1995 M. Raja Jayachandra Rathore's [2] body was identified by his false anterior teeth.

In 1998 Alexander et al. concluded from his research in South Australia that the dentures are not labelled regularly by the dental practitioners due to cost, lack of awareness of standards and recommendations.

Present

In September 2001 DNA extracts from tooth brushes of the victims were used in identification of victims in WTC disaster in U.S.

In 2007, Hideo Matsumur and Saji Shimoe described a simple method for identifying the citizenship/nationality of denture wearer by marking the country code telephone number inside the denture base.

In 2008 it was declared that the Swedish ID-Band has become the international standard and Federation Dentaire Internationale (FDI) accepted method of denture marking system.

Medicolegal Importance of Denture Marking Systems

(1) Identification of the dead or deceased when all other means have failed.
(2) Identification of individuals for forensic, social and legal reasons.
(3) Victim identification in case of mass disasters like terrorism, bombings, earthquakes, hurricanes, typhoons, air crashes and other transportation mishaps.
(4) Identification of mutilated and decomposed bodies when all other parameters like scars, tattoos, and facial features have failed.
(5) Without valid entity to solve the ensuing problems of death certificate, disposal of diseased property, claiming of accrued money or insurance policies, claim for compensation (in case of traffic accidents) denture marking will definitely help in positive identification of victims.

The American Dental Association [1, 3] has specified certain criteria's for denturemarking:

- The identification should be specific.
- The technique should be simple.
- The mark should be fire and solvent resistant.
- The denture should not be weakened.
- The mark should be cosmetically acceptable.

Methods of Denture Marking

Denture marking methods [1, 4] have been divided broadly into "surface marking" and "inclusion methods".

Surface marking methods	Inclusion methods
1. For complete dentures	1. For complete dentures
• Engraving method	• Lose inclusion method
• Embossing method	• Youngs method
• Invisible ink method	• Dippenars method
• Fibre tip pen method	• Reesons method
• Heaths method	• Clear acrylic T bar method
• Stevensons method	• Olivers method
• Weckers electro pen method	• Lenticular card method
• Laser etching method	• Bar coding method
• Onion skin paper method	• Radio frequency identification tag
• Denture bar coding method	• Lead foil method
	• Metallic band according to Swedish guidelines
	• Photograph inclusion method
	• Min I Dent method
	• Data matrix code
	• Microlabelling
	• Cast embossed identification plate
	• Ceramic crown engraving method
	• Memory card method

Surface Marking Methods/Engraving Methods

In the surface marking method, the marks are located on one of the denture's surface and can be done by "scribing or engraving" the denture itself. These methods are simple, cost effective, less technique sensitive and quick. They are as follows:

Fig. 1 Embossing method

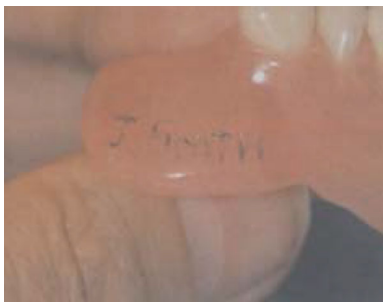

Fig. 2 Heath's method

Fig. 3 Stevenson's method

Engraving Method

In this technique, letters, or numbers are engraved with a small round dental bur on the fitting surface of the maxillary complete denture [4].

Disadvantage: Food entrapment occurs in the engraved grooves.

Embossing Method

The patients initials are scratched with a dental bur on the master cast. This technique produces embossed lettering on the fitting surface of the denture.

Disadvantage: This technique has been associated with malignancy, possibly due to continued tissue irritation [4] (Fig. 1).

Invisible Ink Method

Harvey [5] described a method wherein the patient's details are written with an invisible ink that is rendered visible by ultraviolet light. This is useful on acrylic resin dentures of those patients who object to normally visible identification marks.

Disadvantage: The mark is not readily visible and examination under special conditions is required to determine its presence [6].

Fibre Tip Pen Method

Patient's details are written on the tissue-fitting surface or the polished surface of the denture with a fibre-tip pen. The patient's identification details are then covered by at least two thin coats of varnish in order to prolong the life of the marking [5].

Disadvantage: This method resulted in an unesthetic denture.

Heath's Method

Heath [5] introduced a technique where the identity mark was made with spirit based pen or pencil and covered with a clear base polymer dissolved in chloroform. Later on Heath modified his technique by application of dental sealants instead of chloroform as it is a known carcinogen [5] (Fig. 2).

Stevenson's Method

A scalpel blade [5] is used to make an identification mark on the distobuccal flange of the denture and the mark is then highlighted with a graphite pencil.

Disadvantage: The mark did not last for a long period (Fig. 3).

Wecker's Electro Pen Method

Wecker described an electro pen to engrave patient's details on metal removable and fixed partial dentures [5]. Electro pen has a sharp tip that rotates to write on metal.

Laser Etching Technique

A copper vapor laser [4] (CVL) is used to etch patient's identification into the metal surface of a partial denture. The CVL beam is focused and delivered to the material surface by the two-axis scanner mounted with mirrors. A CVL can label the cobalt-chromium components of dentures easily, legibly and reduce the font size of the data.

Onion Skin Paper Method

Jeffrey [6] described the use of an onion-skin paper with a carbon marker inscription that is applied to the denture

base at trial closure. After processing, the paper is peeled from the denture, leaving a carbon impregnation of the code in the surface layer of acrylic resin.

Denture Bar Coding Method

A bar code consists of a machine-readable code of a series of bars and spaces printed in defined ratios. The technique described for denture bar coding involves printing a number code on paper, photographing the paper, making and transferring the negative to a piece of silk. An image of the bar code appeared on a prepared faience, by a machine that forced the paint through the silk, when heated to 860 °C for 30 min in an industrial porcelain oven. The bar code is directly placed onto the denture surface and cyanoacrylate resin is painted to conceal the marking.

Disadvantage: Incorporating the bar code into the curved denture flange is relatively cumbersome due to rigidity of the laminated strip [4].

Inclusion Methods

The inclusion methods involve incorporation of the identity mark within the denture base material, hence rendering them relatively permanent. Various materials with patients details can be incorporated into the dentures by either pre or post fabrication methods.

Lose Inclusion Method

Lose [5] described a technique wherein the patients name was typed on a piece of "onion skin" paper and incorporated within the fitting surface of the denture during the packing procedure. It is a simple, quick and cost effective method of denture marking (Fig. 4).

Young's Method

Young [5] proposed a technique wherein a 0.5–1 mm deep groove is cut into the buccal flange of the denture, the length of which corresponds to the length of the patient's name. An ordinary ball point pen or felt tip pen is then used to print the patients name in the recess before it is sealed with fissure sealant. It is a simple, quick and cost effective method (Fig. 5).

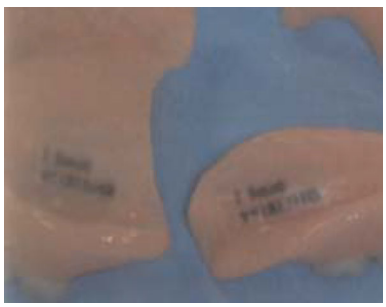

Fig. 4 Lose inclusion method

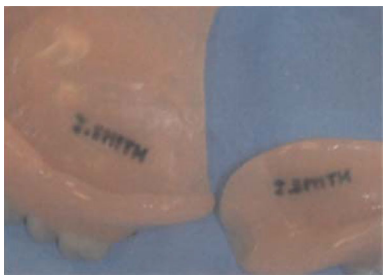

Fig. 5 Young's method

Fig. 6 Dippennar's method

Dippennar's Method

Dippennar [5] introduced a technique wherein a soft metal band either typed or engraved with the patient's details was inserted into the predrilled cavity of 2–3 mm width. The metal band is fire resistant which is required during fire accidents (Fig. 6).

Reeson's Method

Reeson [5] used 9.5 × 0.125 mm thick stainless steel tape of desired size. Patient's name, identification number, and country of origin was engraved with rosehead bur on the polished surface of the steel tape and incorporated into the fitting surface of the denture during trial packing. This technique is simple, cost effective and requires no special equipments. The stainless steel tape is fire resistant. The only disadvantage arises when relining has to be done, but this can be overcome if denture is relined with clear acrylic resin which will allow identification plate to be visible [5, 7] (Fig. 7).

Clear Acrylic Resin T-bar Method

A T-shaped clear polymethylmethacrylate resin bar is constructed by preparing a wax bar which is flasked,

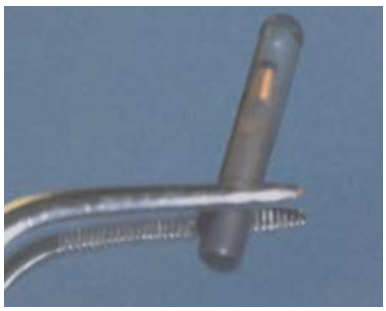

Fig. 7 Reeson's method

packed, processed, and finished in clear polymethylmethacrylate resin. An identification printed label (reduced in size, print-face inward) is fixed against the flat section of the bar. It is then surface polished to produce a clear window displaying the identity label. This procedure is easy, inexpensive and time-effective [4].

Oliver's Method

In this method patient's details are written with a Lumicolour 313 (Staedtler) permanent marker [5] on a 0.3 mm thick rectangular sheet of heat cure acrylic resin. The strip marked with the patient's name is inserted when packing at the trial closure stage. It is then covered by a layer of very thin acrylic resin dough. The flask is carefully closed and the denture is processed. The advantages of using polymethylmethacrylate sheet as a name tag material are: (i) the tag and base are the same material and therefore compatible and (ii) if the tag moves during packing, and a corner protrudes through the denture surface, an acrylic resin tag can be corrected easily. A denture containing a protruding paper or foil tag would require considerable remedial action [3, 5] (Fig. 8).

Incorporation of Lenticular Card

Lenticular lens is used to produce images with an illusion of depth, morph or the ability to change or move as the image is viewed from different angles. Lenticular printing is a multi-step process consisting of creating a lenticular image from at least two or more existing images, and combining it with a lenticular lens. Each image is sliced into strips, which are then interlaced with one or more of the other images. These are printed on the back of a synthetic paper and laminated on the lens The most common materials used for making lenticular images are polyvinyl chloride (PVC), amorphous polyethylene terephthalate (APET), acrylic, spectra, and polyethylene terephthalate glycol (PETG). The lens is incorporated in the channel cut on the denture and auto-polymerizing clear acrylic resin is added around and not on the identifier.

Fig. 8 Oliver's method

Fig. 9 Lenticular card method

Advantages: The lenticular card shows no signs of fading or deterioration when placed in water. It does not require special glass or device to read the data, like computer or hand-held reader and does not interfere with the oral function because of its small size. Lenticular printing is a simple, cheap and quick method [8] (Fig. 9).

Incorporation of Bar Codes

Some of the basic requirements of bar coding are as follows [9]:

1. Must be easy to incorporate.
2. Must give definite information in every situation.
3. Must not alter the structure or properties of the material of the dentures.
4. Must not affect adaptation of the dentures to the supporting tissues.
5. Must not affect aesthetics.
6. Must resist high temperatures.
7. Must be inexpensive.

The bar code is placed into recess created in the denture base which is then finally covered with autopolymerising resin [1, 4] (Fig. 10).

Radio-Frequency Identification Tag Incorporation Method

RFID stands for radio-frequency identification [5], which is a wireless electronic communication technology. Radio-frequency identification technology was first introduced in 1940, during World War II, and used to identify aeroplanes

Fig. 10 Bar code method

belonging to the Royal Air Force. A serial number that identifies a person is stored in a microchip with an attached antenna which together is called an Radio-frequency identification -tag or transponder. The antenna enables the chip to transmit the serial number, or other information to a reader. The reader converts these radio waves into digital information which is then passed to a computer with applications to interpret it. Another feature of RFId-tags is a read/write function to which new data can be transmitted [5, 10].

Advantages

1. The transponder with a unique identification number, allows individual tags to be identified within a group.
2. It is a cosmetic, rapid and reliable method requiring no special training to set the tag in the denture.
3. Large amount of data can be stored without weakening of the denture and relining or rebasing of the denture can be done without removing the device from the denture.
4. The chip is resistant to disinfectant solutions (Fig. 11).

Incorporation of Lead Foil

This method describes a radiographic technique in which a lead foil [1] marked with patient details is sandwiched between two layers of resin during processing of the denture. After processing the denture, radiograph can be taken

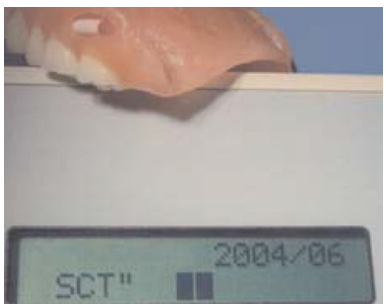

Fig. 11 Radio-frequency identification tag

Fig. 12 Lead foil

to visualize the patient details marked in the lead foil incorporated inside the denture.

Advantages: It is a simple, easy and a quick method. It is a durable and cosmetically acceptable method fulfilling all the requirements of ADA. The strength of the denture is not jeopardized [1, 11] (Fig. 12).

Incorporation of Metallic Band (Based on Swedish Guidelines)

The Swedish ID-Band (SDI, AB, Sweden) is a stainless steel band with ten figure personal number having patient details. The personal number consists of a letter (S- for Sweden) and a ten-figure number. The first six digits are the patient's birth date, date month year with zero as a prefix to numbers smaller than ten. The next three digits is the birth number and the last digit indicates the sex [12].

Advantages This ID-Band can withstand temperature up to 1,100 degree C.

Stainless steel is a well established material for dental appliances and there is no documented case of it causing allergies. It is the most durable form of marker in cases of severe conflagration [1] (Fig. 13).

Photograph Inclusion Method

This technique makes use of the patient's photograph which is embedded in clear acrylic denture base. The name, age and geographic location of the patient are written on

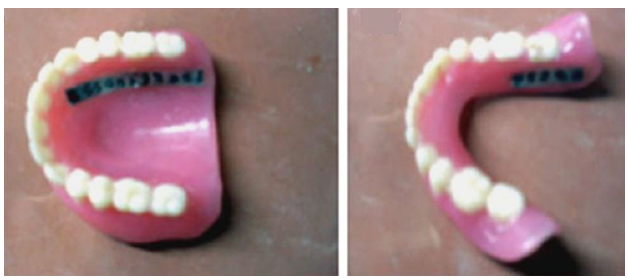

Fig. 13 Swedish metallic band

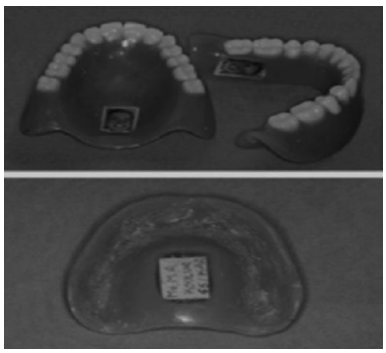

Fig. 14 Photograph inclusion method

the obverse of the photograph using a micro-tip graphite pencil. The marker is particularly useful in the countries with low literacy rate where a photograph is the easiest method of identification [13].

Advantage: The identity is easily ascertained by lay persons with the unassisted eye (Fig. 14)

Incorporation of Min. I. Dent

Patient's details are typed on Min. I. Dent denture identification strip [14] and the strip is heated in an oven at 325 °C for 30 s to 1 min. This allows shrinkage of lettering or numbers and the strip becomes a chip. The chip is trimmed to required size using carbide bur. A groove is cut into the denture and the chip is incorporated into the groove and sealed with orthodontic resin.

Incorporation of Data Matrix Code

The matrix marking [15] is a thermally resistant substrate wafer of 4 mm diameter. It is comprised of two dimensional data matrix of light and dark coloured regions representing binary 0 and 1 it is scanned using M210 hand held scanner. When embedded into auto polymerising acrylic resin, 60 % of the wafer dissolved into the monomer and was unusable. Hence direct laser engraving of the code into ceramic disc was carried out. The discs were 4 mm in diameter and 0.5 mm thick. Such matrix codes can contain 16 upper case alphanumerical characters. The coded ceramic discs were then incorporated into the heat cured clear resin at the flasking and packing stage of denture fabrication.

Microlabelling Method

This method can be performed using microlabels made of various materials. The various methods and materials used for the same are:

(i) In one method label was made using a labelling machine PT 20 PTouch [16]. Personal information was printed either on a 9 or 12 mm, white or clear label tape. Clear label is preferred to minimize the esthetic impact of the label. The label can be inserted at the time of denture processing or can be inserted after denture finishing, later method gives predictable results.

(ii) In another technique microlabel was made by putting personal identification information in a graphic image and recording on an instant Polaroid slide film [17]. Information was keyed into the computer slide making format with a font size of 22 to produce a 15 × 3 mm label. The graphical image on the screen was automatically sent to the Polaroid digital palette, which contained an instant digital slide film. It was then transformed into a 35 mm slide which was later on cut as per the requirements and placed into 1 mm groove on the denture surface. The label was coated using autopolymerising clear acrylic resin.

(iii) Patient's personal identification information was computer printed [18] using a character of 8-point font size. The label was then photocopied onto a transparency film in 50 % reduced size and chemically treated with cyanoacrylate adhesive solution. The microlabel was then incorporated into denture during the packing stage or alternatively the microlabel could be incorporated after the denture fabrication.

(iv) A slight alteration of Ling's method involved printing personal data directly onto the overhead transparency sheet of adequate size. Cyanoacrylate adhesive is placed over the printed matter. Care is taken not to rub the adhesive over the marked portion and a same size blank transparency sheet is placed over it. By doing this the printer toner is placed away from the monomer of denture base resin [2]. Thus the detoriation of legibility is reduced. The two joined sheets are cut with sharp scissors for restricting the size of label. The printed identification label is incorporated into the denture by either prefabrication or postfabrication technique.

(v) In this method the patient's details are typed on a strip of absorbent tissue paper [19], placed on the internal surface of the denture and saturated with acrylic resin monomer after the final trial packing of the denture. It is placed in the denture surface where subsequent adjustments or breakage of the denture is highly unlikely. When cured, the embedded name on the strip is readily visible (Fig. 15).

Incorporation of Embossed Identification Plate into Partial Denture Frame Work

This is a simple technique in which embossed tape with patient details is placed into the major connector portion of the plastic pattern of cast partial denture framework and the

Fig. 15 Microlabelling method

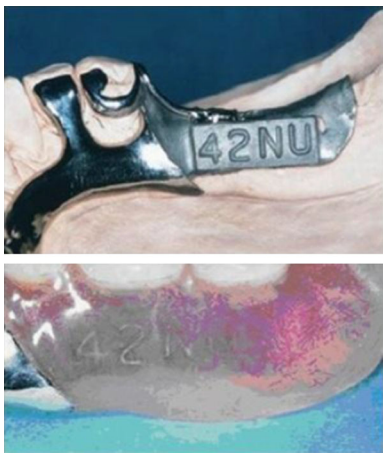

Fig. 16 Embossed identification plate

casting is completed. The patient details are visible in the metal framework of the cast partial denture [1].

Advantages Incorporation of identification mark on a cast partial denture framework would ensure identification even in more extreme situations like fire and traffic accidents [1, 4] (Fig. 16).

Ceramic Crown Engraving Method

After baking the opaque layer of porcelain, dentin porcelain is applied and initials of name of the patient or letters are carved with the brush. Stains are applied on carved initials followed by enamel porcelain application shaped with soft brush so that the initials are maintained. Few initials can be carved in crown and bridges due to lack of available space [1, 19].

Incorporation of Memory Card

Memory card is an electronic storage device used to store a wide range of data files such as audio and video clips, images and text documents. It is small in size, re-recordable and it can retain data without power. In this method, all the relevant information regarding the patient's identification and photograph were stored in the memory card. The card (15 × 11 × 0.7 mm) is wrapped in cellophane sheet (to protect it from polymer powder and liquid) and is placed on the external surface of the palatal aspect of the denture and covered with auto polymerizing acrylic resin [20].

Advantages: It does not interfere with oral function or strength of the denture because of its small size. No special training or equipment is required for fabrication of such a labelled denture. The data can be read by any personal computer using windows operating systems with the help of memory card reader.

Sites for Location of the Denture Marker

Usually cameo or polished surface of denture is preferred but if esthetics is concerned, intaglio or impression surface is used. If the denture label is placed on intaglio surface, they become invisible when relining is done. The most appropriate sites for the location of denture marker are [1]:

1. Posterior buccal surface of maxillary denture.
2. Lingual flange of mandibular denture.

These areas are chosen because

- Accessibility to the reader.
- Sufficient thickness of resin to incorporate without any technical difficulties.
- Aesthetics of the denture is not affected.
- Other sites are
- Within the palate or buccal to tuberosity regions
- In case of fixed prosthesis like crowns the initial or identification number is engraved usually on lingual surface of anterior and posteriors. Occlusal surface of the posteriors are not preferred because of possibility of loss of details during occlusal adjustments.

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Advantages of Denture Marking Systems

- Patient identification in natural and mass disasters.
- Appliance identification in geriatric institutions.
- Retrieval of dental records in cases of emergencies like accidents.

- Diagnostic and decision support in medico legal issues.
- Recording and storage of patient's details on an easily accessible system.
- Complete and assured documentation of patient's details since the marked dentures are fabricated by trained professionals.
- Ability to trace suppliers, materials, equipments.

Disadvantages of Denture Marking Systems

- All the ADA specifications are not fulfilled by the denture marking systems.
- If the denture labelling systems are placed on the intaglio (impression) surface they become invisible when relining is done.
- After inclusion of the marker in the dentures changing the patients detail becomes a tedious job.
- Certain denture marking systems are expensive and require special equipments to read the data.
- Data from denture marking systems requiring special equipments to read the data like barcodes, memory card, RFId cannot be obtained quickly in cases of emergencies like road accidents, mass disasters etc.
- There is fading of certain identification marks like photograph, bar codes microlabels etc. over a period of time.
- Surface engraving methods leads to food lodgement and the details can be changed without the consent of the patient and the dentist.
- Few denture marking systems are available for crowns and FPD's.

Conclusion

The American Board of Forensic Dentistry has given four conclusions from dental evidence [1].

Positive identification—data available was accurate without discrepancies.

Possible identification—data was not confirmatory.

Insufficient evidence—insufficient data for conclusion.

Exclusion—data is clearly inconsistent.

The most acceptable method of denture marking considering economy and simplicity of the technique is the lead foil, Swedish metal band and lenticular card incorporation technique. The barcode system and microchip permit storage of large amounts of information, but at the cost of a high price. Also both these systems need to have a hand-held reader or computer to read the data [8]. Labeling of all dentures is recommended by most international dental associations and forensic odontologists. In fact, in some countries and certain states of the USA, the labeling of dentures is regulated by legislation. As part of the obligation of the profession, a dental practitioner needs to maintain meticulous dental records of his patients. Denture marking should be compulsorily carried out for hospitalized patients, unconscious patients and patients in geriatric institutions. There is a strong need to adopt an international policy for denture marking and international collaboration should be encouraged, with different opinions from the world-wide community of forensic odontologists discussed and with the aim of reaching some kind of consensus for the future.

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