COPPER VAPOUR LASER ID LABELLING ON METAL DENTURES AND RESTORATIONS

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ABSTRACT

Denture marking is accepted as a means of identifying dentures and persons in geriatric institutions, or post-mortem during war, crimes, civil unrest, natural and mass disasters. Labelling on the acrylic resin component of the denture can easily be damaged or destroyed by fire but on cobalt-chromium components it would be more resistant. A copper vapour laser (CVL) can be used to label the cobalt-chromium components of dentures and metal restorations easily, and legibly, and miniaturised for the incorporation of more personal particulars necessary for the identification of the deceased person. The CVL beam is focussed by its optics and delivered to the material surface by the two-axis scanner mounted with mirrors. A personal computer controls the movement of the scanner and the firing of the CVL. The high peak power of the pulsed CVL is focussed to very high energy density producing plasma ablation of the alloy surface. Very fine markings of a few microns width can be produced enabling the storage of detailed information of the deceased person on a metal surface for the purpose of rapid identification. **(J Forensic Odontostomatol 2003;21:17-22)**

Keywords: ID-markings, forensic odontology, copper-vapour laser, metal dentures and restorations

INTRODUCTION

Denture marking is necessary for a number of social and forensic reasons. These include the identification of dentures during construction in the laboratory, the identification of persons in geriatric institutions and hospitals who are unconscious or suffering from amnesia, senility or Alzheimer's disease and the post-mortem identification of victims of crime, accidents, mass disaster, civil disorder, war, terrorism and the like. The important role of dental evidence in the positive identification of deceased victims has become widely recognised.[1-4] The massive public awareness after mass disasters requires prompt identification of the victims which depends heavily upon ante-mortem dental records supplied by dentists.[5,6] The records may include dental charts, radiographs, models and even photographs of patients, the last three items providing evidence for visual comparison but dental charts are essential for matching the surviving restorations and prostheses as described on the post-mortem charting sheets. Delays in identification of deceased bodies can cause social problems such as the delay and arrangement of the proper burial rites and procedures. It can also cause inconvenience and hardship because of legal problems and may delay insurance claims and inheritance of property.

When sheltered from fire, complete dentures are an important potential source of information for identification, particularly if they are legibly marked with numbers or names which can be traced to a record of the wearer. Such data can even survive a fire if scribed, embossed or engraved on a high melting point metal foil cured into the denture base.

Denture wearing patterns vary according to the location and age of the wearers. According to the World Health Organisation,[7] in Europe the proportion of 65-74 year-olds who are edentulous varied from

12.8% to 69.6%, with the mean number of teeth ranging from 15.1 to 3.8. These high numbers suggest that denture marking should be mandatory, a procedure that has been recommended by the FDI since 1972, and is now law in seven states in the USA.[8] In Sweden, the Swedish Board of Health and Welfare recommends that all patients should be offered the opportunity to have their dentures marked, but the patients can choose to refuse. The marking of all new dentures is recommended by the Australian Dental Association. The use of a patient's national identification number together with letters indicating the country of origin instead of inserting the patient's name was first described by Thomas.[9]

Various methods of denture marking have been described[8-21] and they can be classified under one of the following categories:

1. writing on the surface of the denture,
2. engraving on the surface of the denture or the surface of the cast (before processing the denture) and
3. inclusion of paper, plastic or metal labels or ceramic chips into the acrylic components of the denture during[14] or after processing the denture.

However, markings on non-fireproof labels in the denture acrylic resin may be damaged or destroyed if the denture is burnt in a fire. Fireproof metal foils embossed by a typewriter are available commercially and where applicable the metal component of a removable partial denture could be engraved, but this is difficult.[16] The engraving would normally be done by hand so it may not be legible and the characters would not be sufficiently small to incorporate enough personal particulars. Various micro-labelling techniques have also been developed[19-21] where more information can be included. Fonts of conventional size (10 to 12) only allow the country code and personal identification numbers to be accommodated but fonts of size 6 or smaller allow the person's name, gender, country of origin and personal identification number to be included. The telephone number of next-of-kin can even be incorporated, allowing more rapid identification and notification.

A particularly attractive option is the use of high power lasers for the micro-labelling of dentures. Lasers are well established in industry, especially in the cutting and welding of metals and their use is also becoming common in biomedical technology with various applications in dental procedures such as the cutting of dental enamel and dentine, soft tissue surgery, periodontics and certain endodontic procedures.

In order to be able to engrave on metallic surfaces, pulse lasers with high peak power operating at high repetition rates are necessary. Some of the lasers that can be used are excimer lasers such as KrF lasers emitting output in the UV wavelengths which are generally too expensive and solid state Nd-YAG lasers which are suitable laser sources but their infrared output wavelength (1.06 mm) is less than ideal due to its lower absorption by metallic surfaces. Its frequency doubling to the yellow-green wavelength (0.53 mm) provides better light absorption properties although it means a lower operating efficiency. On the other hand, recent advances in high power metal vapour laser technology have enabled the engraving and labelling of metal objects not only to be possible, but also miniaturized to a high degree. This report presents a method of labelling cobalt-chromium metal alloys, metal restorations and fire resistant metal foils using a high power copper vapour laser (CVL).

Copper vapour lasers have a high level of efficiency with their output wavelengths of 511 and 578 nm and are normally operated at high pulse repetition frequency of 5 to 20 kHz. Typical output power is in the range of 5 to 20 W with a single pulse energy of more than 1 mJ. With a short pulse length of 15-20 ns, the CVLs offer a useful laser source with high peak power exceeding 50 kW. Using an optical lens, a 1 cm diameter output laser beam can be focussed to a diffraction-limited spot of a few microns in diameter. This will then produce an intense spot of light with power density exceeding tens of gigawatts per cm^2 which leads to the formation of plasma ionization at the surface of the material. The plasma formed produces micro-ablation leading to permanent markings on the surface of a metal. By scanning a pair of mirrors mounted on two galvanometers in two perpendicular axes, and controlled by microcomputers, micro-engraving of information on dentures can readily be made using much the same technology as graphic plotters.

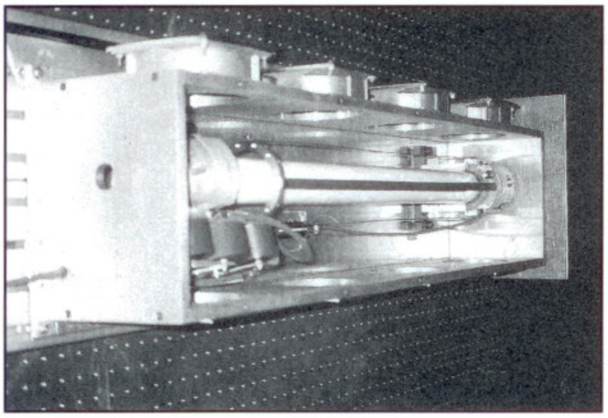

Fig.1: The prototype Copper Vapour Laser marking system used in the project

MATERIALS AND METHODS

The laser used in this project was the copper vapour laser* (CVL) (Fig.1) operating as a high repetitive rate and longitudinal discharge laser device. The laser is operated by charging a 2 nF capacitor to more than 10-12 kV and discharging it into a neon filled ceramic cavity. Operating at a high repetitive discharge rate, the ceramic cavity is heated gradually to a high temperature in the range of 1300 to 1600°C by the waste heat generated by the discharge. At this high temperature, copper filings placed inside the cavity vapourize which now takes part in the electrical discharge leading to the excitation and de-excitation of the copper atoms. With proper design of the electrical excitation circuit, two visible laser output wavelengths of 510.6nm and 578.2nm are obtained.

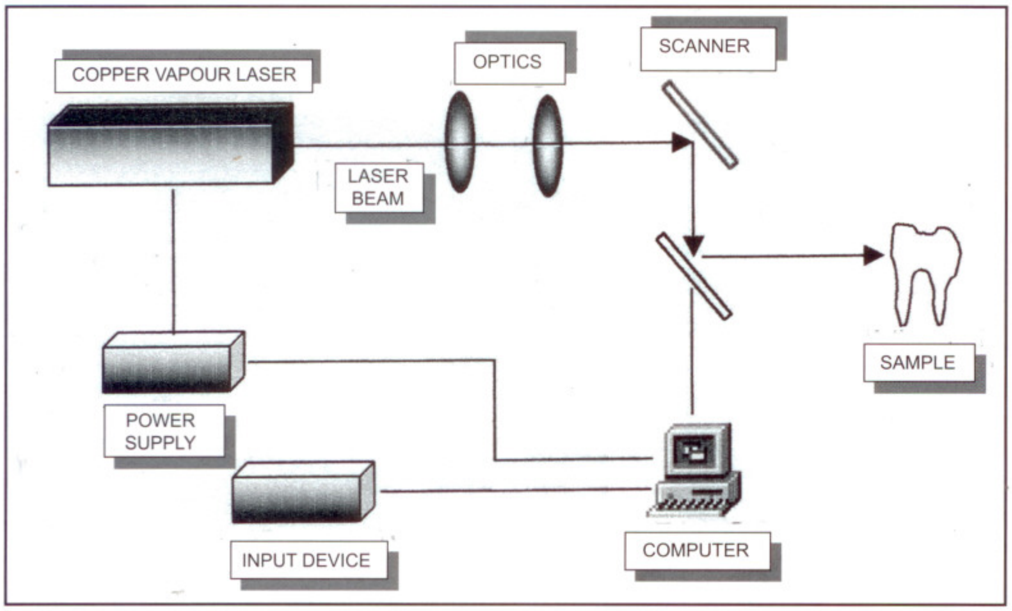

Fig.2: The schematic representation of the CVL marking system

The present CVL operates at 7 kHz with a peak power of 10 kW and pulse width of 20 ns with an average output power of 1.4 W (the experimental scheme is shown in Fig.2). A 5 cm diameter pyrex lens with a focal length of 12.5 cm is used as the focussing optical element. The lens (Fig.3) focuses the CVL beam down to a spot size of less than 10 mm in diameter and a two-axis scanner (Fig.4) delivers this focussed beam onto the material surface (Figs.5-7). The characters to be engraved were edited and entered into a personal computer using standard software converting the characters into a digital vector array. The microcomputer controlled the movement of the scanner and the firing of the laser. In between the different strokes in the writing of the characters as well as in the spacing of the characters, an accoustico-optic modulator is used to deviate the beam away from the scanned surface.

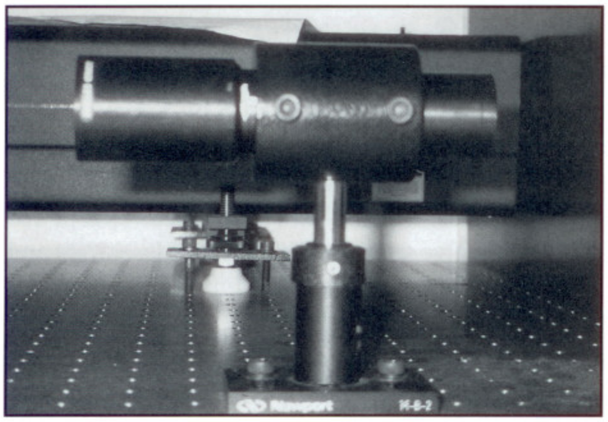

Fig.3: The laser optics of the system focus the CVL beam down to less than 10 μm

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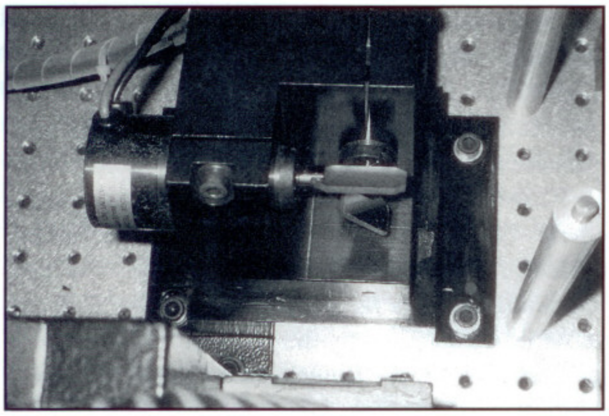

Fig.4: The two-axis scanner delivers the focussed CVL beam onto the material surface

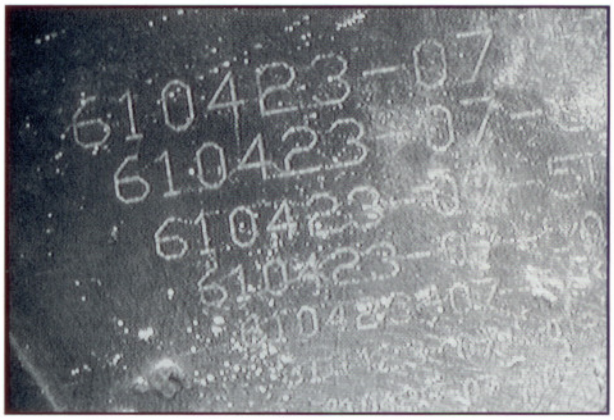

Fig.6: The sample ID marking of varying, decreasing size made on a cobalt-chromium test plate, seen under a stereo-microscope. The height of the characters in the third row is estimated to be 250 μm at 20X magnification

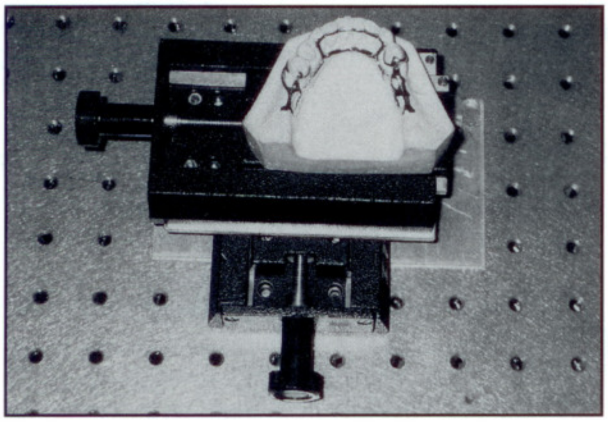

Fig.5: The cobalt-chromium denture to be marked, placed on the target stand

Fig.7: ID marking on the surface of an inlay, as seen under a stereo-microscope

RESULTS

The high directionality of the CVL makes it possible to achieve good focussing of the beam to a spot size of a few microns and thus delivers enough power to plasma-ablate the intended target surface. The engraving of cobalt-chromium alloy in prostheses, metal foils and other metal restorations is thus possible and effective. With fine engravings typically of less than 10 mm in width with an overall character height of around 200 mm, a large amount of data can be stored on the surface of the dentures or crowns. On the other hand, due to the generally curved surface of the dentures, engravings are made over a relatively small surface area of 5 by 5 mm^2 area to avoid undue beam defocussing effects. It was found that the plasma ablation process can effectively engrave most metallic alloy surfaces, except for highly reflective surfaces which reflect laser light and lead to inefficient engraving. Furthermore, due to the typically small energy of 1 mJ per pulse, the plasma ablation process is localised to the small spot area. The low energy laser pulses also produce insignificant shock waves to stress the material of the denture.

DISCUSSION

In any major disaster the rapid recovery and identification of victims' bodies are a priority. The victims may be of diverse nationalities and obtaining ante-mortem dental records for comparison with post-mortem records can be time consuming and difficult. It would therefore be very helpful if victims could be identified by features that are found on the body, be they inscriptions on a partial denture or on metal restorations.

The copper vapour laser enables clear and permanent engravings on the metal alloy surface to be made. As the size of the printing can be adjusted even down to microscopic level, more extensive personal particulars can be incorporated, including the wearer's full name, gender, nationality, personal identification number, country of origin and even telephone number of next-of-kin, e-mail address and other relevant information. This information facilitates speedy person identification and early notification of relatives. Although the initial cost of setting up a CVL is high, the cost of engraving is very low or negligible. The only drawback is the long warm-up time of the laser cavity of at least 45 minutes before laser radiation is emitted CVLs however incorporate a standby resistive heater to maintain cavity temperature overnight to avoid a cold start and laser emission can then be obtained after 10-15 minutes of electrical discharge of the laser tube.

CONCLUSION

Engraving on the metal components of dentures, fire-resistant foils or metal restorations ensures the durability of the mark because these components will withstand fire, which often follows a major disaster, or other degenerative processes. The CVL technology furthermore presents the option of mini-aturizing the engraving so as to include considerably more information than is usually possible.

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