J Forensic Sci, March 2009, Vol. 54, No. 2
doi: 10.1111/j.1556-4029.2009.00987.x
Available online at: www.blackwell-synergy.com

Raymond Richmond,[1] B.Sc., M.Phil. and Iain A. Pretty,[2] B.D.S.(Hons), M.Sc., Ph.D., M.F.D.S. R.C.S.(Ed)

A Range of Postmortem Assault Experiments Conducted on a Variety of Denture Labels Used for the Purpose of Identification of Edentulous Individuals

ABSTRACT: Forensic organizations worldwide have recommended that dental prostheses should be labeled with at least the patient's name and preferably with further unique identifiers such as social security number, etc. The practice of denture marking has been conducted over many years and several denture marking systems have been reported in the dental literature. However, very little is known about the resilience of such systems to conditions experienced in the majority of post- and perimortem assaults. The purpose of this investigation therefore, was to expose a selection of 10 denture labels to a series of hostile environments. Results of the study indicate that the majority of the denture labeling systems appear capable of withstanding a range of common, and not so common postmortem assaults. With regard to thermal insult, however, most performed badly with the exception of a label constructed from stainless steel orthodontic band. However, another label in the form of an electronic RFID-tag performed above expectations in the majority of experiments. Furthermore, its cosmetic appearance has proven most popular with many patients.

KEYWORDS: forensic sciences, dentures, prostheses, labeling, identification, dental

The value of natural teeth (and associated oral tissues) to forensic dentistry is evidenced many times over in the dental literature (1). The edentulous patient on the other hand presents a more perplexing problem as far as determination of identity is concerned (2,3). While 16–18 matching elements are usually required for a positive identification by fingerprint analysis, an appropriate number of comparison features for dental identification has not yet been established, owing to the infinite number of possibilities (4). Hence, in the case of the edentulous individual, the marking of dental prostheses provides an opportunity to give the anonymous/stereotype denture the uniqueness inherent to the natural dentition (1).

There are several documented benefits associated with the practice of denture marking. First and foremost, the procedure facilitates immediate identification of the wearer or conversely, identification of the dentures themselves. The former would include identification of the wearer postmortem, e.g. in cases of forensic crime scene analysis. The latter would include separation of the wearer's dentures from those of other individuals (5). Personal identification obtained from dental prostheses has been used for hundreds of years. The earliest recorded cases of identification involved single cases, i.e., people who had met a sudden death. One of the earliest classic examples cited in the literature relates to the Countess of Salisbury, who in 1835 was burned beyond recognition except for her gold denture (6). In fact, dentures in the 19th and early 20th century often had letters and numbers punched into the gold portion of the denture (7). Even unlabeled dentures have facilitated the identification of deceased individuals. However, the process of identifying a victim's body by means of an unmarked denture is only possible if a characteristic mark or trait is observable (8). Certain denture characteristics may be traceable to a particular dental practitioner, dental technologist, or laboratory.

In 1939, a body was found in the county of Yorkshire, U.K. and was identified by the repairs which the deceased person's dentist recognized. In the United States, one of the earliest cases of recorded incidents pertained to the murder in 1849 of a wealthy physician named Professor George Parkman by Dr. Webster, a professor of chemistry at the Medical College of Boston. Dr. Parkman was dismembered by his murderer, and partly burnt in a furnace. However, the janitor noticed that the furnace had been used at an unusual time of the night, and upon investigation, fragments of a gold-based denture were found in the furnace and in a tea chest, which were in Dr. Webster's laboratory. The fragments of denture were subsequently recognized by a dentist who had made it for Dr. Parkman (7,9).

History has shown that the disposal of a dead body has always proved a challenging exercise in any planned murder. The "perfect murder" involves a reasonable explanation, a satisfactory reason for the victim's disappearance, or the complete destruction of the body and the elimination of any identifiable residual traces (10). In 1949, the mass murderer, Haigh, thought he had disposed of his victim, Mrs. Durand-Decon by dissolving her body in sulfuric acid; however, her dentures remained intact after being recovered from the black sludge in the bottom of an acid bath in Haigh's possession and were subsequently identified by her dentist (Mrs. Helen Mayo) who purportedly identified them from repair work that had been performed on the denture. Hence, it was largely on this evidence that Haigh was eventually convicted (11).

In cases of mass disaster, marked dentures have also proved to be an invaluable source of postmortem information. Acrylics and porcelains used in denture fabrication are very resistant to most degenerative processes with the exception of fire (12).

[1]Restorative Dentistry, School of Dentistry, University of Manchester, Higher Cambridge St, Manchester M15 6HF, United Kingdom.
[2]Dental Health Unit, School of Dentistry, University of Manchester, 3A Skelton House, Manchester Science Park, Manchester M15 6SH, United Kingdom.

Received 6 May 2008; and in revised form 18 June 2008; accepted 21 June 2008.

However, it has repeatedly been reported that if dentures are retained in the mouth very little destruction occurs even in the severest cases involving bodily incineration. Haines (9) appears to concur with this view having reported that in many cases where limbs have been completely burned off, enough denture material has survived to give a positive identification. This is particularly the case with the posterior sections of both acrylic and metal dentures (13).

As mentioned previously, certain denture features may be recognized by their provider and/or manufacturer. The type of tooth, both anterior and posterior, denture base material including clear palates, soft linings or tooth arrangements are examples of features cited by Thomas (8). Haines (1973) proposed that dentures must be examined in detail and their features noted, for example:

- The color of the acrylic and the presence of stippling.
- The material, size and mold of the teeth.
- Laboratory marks, numbers, and initials.
- Shape of the relief area.
- The shape, type, and depth of the post dam.
- The presence or absence of a labial flange, i.e., complete or gum fitted.
- The coverage or otherwise of the retro-molar pads.
- Details of repairs, relines, and soft linings.
- Whether plaster models or spare dentures are available.

When all of the aforementioned characteristics are considered for each case, many of the dentures discovered in a mass disaster situation can be identified, at least by exclusion.

The practice of denture marking has been conducted over many years and several denture marking systems have been proposed (3). However, very little is known about the resilience of such systems to the destructive environments in which a human body may be found. The purpose of this investigation therefore, was to expose a selection of denture marking systems to a range of postmortem assaults in order to simulate the type of conditions similar to those found in situations where bodies are discovered.

Methods and Materials

A 10 × 10 × 0.5 cm block was manufactured from polymethylmethacrylate acrylic (PMMA) pink/veined denture base resin. One example each of the following denture identification labels was then placed into the block to a depth of 2 mm before being covered by clear self-cure PMMA (Fig. 1).

FIG. 1—*A 10 × 10 × 0.5 cm block manufactured from polymethylmethacrylate acrylic (PMMA) pink/veined denture base resin. One example of each denture identification label was placed into the block to a depth of 2 mm before being covered by clear self-cure PMMA.*

The following 10 denture identification methods which were selected for the study are presented in the order of top to bottom in two columns:

Position 1 (top left) shows an example that involves cutting a groove of *c.* 0.5 to 1 mm deep into the buccal flange of the denture, the length of which would correspond to the length of the patient's name. An ordinary ballpoint pen or felt-tip pen is then used to print the patient's name in the recess before being sealed with fissure sealant.

Position 2 (below) shows a technique in which the patient's name is typed on a piece of "onion skin" paper and incorporated within the fitting surface of the denture during the packing procedure.

Position 3 shows an example that allows the dentist to write on the surface of the denture using a spirit-based pen or pencil prior to covering the ID mark with a clear denture base polymer dissolved in chloroform.

Position 4 (bottom left), utilizes a standard soft metal band that is either typed or engraved with the patient's details before being rolled up and inserted into a predrilled cavity *c.* 2–3 mm wide. A small wax plug is then placed over the metal band prior to filling the remainder of the cavity with self-cure resin.

Position 5 (top right) is a method involving the use of a typed, commercially produced metal strip (trade name: ID-Band) embedded into the polished surface of the denture and covered with clear acrylic.

Position 6 houses an RFID system consisting of a data carrier, generally known as a tag or transponder. The tag consists of a torpedo-shaped microchip with a coiled antenna, measuring 8.5 mm × 2.2 mm. The transponder may be embedded into either the polished or fitting surface of an existing denture.

Position 7 includes an example similar to that of an ID label that had been produced in a 'P-touch' electronic lettering system (P-touch, Brother Co., Canada). The label used consisted of a 103 μm thick, white or clear laminated strip onto which 2 mm characters are typed, after which it is incorporated into the denture subsequent to its fabrication.

Position 8 is made from a label printed on 35 mm photographic slides via the use of a computer graphics package. The label is embedded into the denture base and covered with clear acrylic.

Position 9 shows an example in which a fine fiber-tipped pen was used to mark a label made from a partially polymerized strip of PMMA before including in the fitting surface of the denture base during the trial packing procedure.

Position 10 (bottom right) utilizes a piece of 0.125 mm thick stainless steel orthodontic tape onto which the patient's details are engraved. The tape is then incorporated into the fitting surface of the denture during the trial packing stage.

In phase 1 of the experiments, six blocks, each containing the aforementioned 10 specimens were then subjected to the following conditions:

- Burial of up to 6 months in acid soils of various levels of pH.
- Immersion in sea water for periods of up to 6 months.
- Immersion in fresh water for periods of up to 6 months.
- Immersion of up to 6 months in concentrated Milton disinfectant.
- Freezing in temperatures of *c.* −20°C for up to 6 months.

In phase II, a further four blocks of specimens were exposed to a range of extremely hostile environmental conditions in order to test them to destruction, e.g.:

Test 1: Immersion in concentrated sulfuric acid for a period of 24 h.

Test 2: Immersion in concentrated sodium hydroxide NaOH for 24 h.

Test 3: Immersion in liquid nitrogen for a period of 3 min.

Test 4: A block of specimens was exposed to a naked flame until the specimen block caught fire and was allowed to burn.

Test 5: Placed in a crematorium furnace at *c*. 800°C for a period of 20 min.

Results

The results of the phase 1 tests are shown in Table 1. The results of the phase I tests showed no change in appearance of any of the specimens after their 6-month ordeal, however, the results of the phase II tests (Table 2) were somewhat different. In test 1 in which the specimens were immersed in concentrated sulfuric acid for 24 h, the surface of the acrylic was completely destroyed. After immersing the specimens in water for a further 24 h to neutralize the acid, the pH recorded was *c*. 3.5. However, when interrogated by the reader, the RFID-tag functioned perfectly. At the other end of the pH scale, i.e., test 2 involving concentrated sodium hydroxide, no change was observed. Test 3 involved the immersion of the specimens in liquid nitrogen for a period of 3 min. In this case, all specimens, including the RFID-tag were completely unaffected; however, the acrylic block sustained considerable damage in the form of crazing caused by thermal shock.

Test 4 involved setting the specimen on fire. The specimen block was then extinguished after 5 min in order to test the function of the RFID-tag. The tag responded normally to the reader. The specimen block was reignited and allowed to burn for a further 5 min. However, when tested a second time, the tag failed to respond. The specimen block was again reignited and left to burn until all of the PMMA was consumed. Fig. 2 shows the results of the experiment, i.e., all that remained of the specimens were specimens number 5, the ID-band and number 10, the stainless steel orthodontic band. Other debris identified were the remains of specimen number 4, the soft metal band that had been rolled into a coil. All that remained of the RFID-tag was the graphite rod on which the copper coil antenna was positioned.

Test 5, in which the specimens were placed into a crematorium yielded similar results to that of test 4.

Discussion

The results of the postmortem assault experiments clearly indicate that, with the exception of fire, even the most fragile denture marking method possesses the ability to withstand a range of chemical and thermal insults. The stainless steel orthodontic band was by far the most impressive denture label tested in that it out performed the commercially produced ID-Band which purports to be able to withstand temperatures *c*. 3000°C. However, is such a property really necessary? With respect to thermal insult, Thomas et al. (12) reported that a denture which remains in the mouth during incineration is very well protected by the surrounding soft tissues (14) and that at least the posterior half to one-third will remain intact. Hence any mark which is present, even one which is not fire resistant, has been proven empirically to survive incineration. However, Ling argued that if a denture is expelled from the mouth (as often happens in violent accidents such as air crashes), and there is a fire, the denture may be destroyed, but its fire resistant marker would remain intact, ready for retrieval (15). Thomas, on the other hand, disagreed with this statement and questioned whether, if found, would such a label be readable or indeed when commingled with the other debris would it indeed be recognized as a denture label (8)? Hence for the aforementioned reasons they concluded that to incorporate a fire resistant denture label would probably be a futile exercise.

It also appears as though even a simple paper label is satisfactorily protected by denture base material. However, empirical studies have shown that dentures made from PMMA absorb relatively small

TABLE 1—*Results of the phase I postmortem assault experiments.*

Type of assault	
Burial in acid soil pH: 4.5	x
Burial in alkali soil pH: 7.5	x
Immersion in sea water	x
Immersion in fresh water	x
Immersion in concentrated Milton disinfectant	x
Freezing in temperatures of −17°C	x

Immersion/burial experiments undertaken for up to 6 months in duration.
x = no change in appearance.

FIG. 2—*Remains of the fire experiment, i.e., the stainless steel orthodontic band, the ID-Band, the soft metal foil, and the remains of the RFID-tag. Featured on the right are the intact versions of the labels.*

TABLE 2—*Results of the phase II postmortem assault experiments.*

Test	Type of Assault	Result
1	Emersion in concentrated sulfuric acid for a period of 24 h	✔
2	Emersion in concentrated sodium hydroxide (NaOH) for 24 h	x
3	Emersion in liquid nitrogen for a period of 3 min	✔
4	A block of specimens were exposed to a naked flame until the specimen	✔
5	Placed in a crematorium furnace at *c*. 800°C for a period of 20 min	✔

x = no change in appearance. |*rad*| signifies a define/destructive change in appearance.

concentrations of water over time when processed in an aqueous environment. In service, further water absorption can occur up to an equilibrium value of about 2%. It has been claimed that each 1% increase in weight in the resin, attributable to water sorption, causes a linear expansion of 0.23% (16). Hence, it was thought that this occurrence may tend to degrade a paper label over time. Woelfel (17), on the other hand, investigated the dimensional stability of dentures during their storage in water. It was noted that these were only minor dimensional changes which were determined to be of no clinical significance. Furthermore, the aforementioned empirical studies appear to be in agreement with Woelfel's findings.

The overall performance of RFID-tag was also impressive. It operated flawlessly in sub-zero temperatures that would completely ruin most other electronic equipment. It also functioned reasonably well in the fire experiment and failure was probably attributable to the low melting point of the soldered joints and/or the melting of the shellac insulation coating of the copper coil antenna. However, if strategically positioned in the posterior section of a denture, the aforementioned argument relating to the protective effect afforded by the head and neck tissues still applies. Where the device scored highly owing to its glass encapsulation was in the experiment involving concentrated sulfuric acid. After being immersed in the acid for 24 h, the surface of the acrylic block had been penetrated to the depth of *c*. 1.5 mm, turning it to a corrosive mush. Even after soaking the specimens in water for 24 h, attempts to cut out the metallic denture labels for further inspection had to be abandoned as both the bur and dental handpiece were beginning to sustain considerable damage. Nevertheless, when scanned, the RFID-tag worked perfectly.

Conclusion

An aging population means the number of edentulous and partially dentate patients is rising (18,19). Hence, in the absence of natural teeth, properly marked complete dentures provide a valuable and cost-effective means of identification for edentulous individuals. An ideal denture marking should fulfill all of the following ideal criteria.

1. The mark carried by the denture must be capable of yielding positive identification.
2. The marking technique must be easy and quick to carry out and cheap to introduce bearing in mind the requirements of (1) above.
3. The mark should, ideally, be fire resistant, and if it is not, it must be placed palatally or lingually in the molar region, so that the tongue can protect it.
4. The marking method should not affect the durability of the denture base material.
5. The mark should be cosmetically acceptable to the patient and as unobtrusive as possible (20,21).

Results in this study have shown that the majority of denture labeling methods reported in the dental literature are capable of withstanding a range of common, and not so common postmortem assaults. By far the most impressive method examined in terms of cost-effectiveness and resilience was the label constructed from stainless steel orthodontic band. The RFID-tag came a close second and its cosmetic appearance has proven popular with many patients (22). A denture identification company based in Australia has begun to compile a database for forensic detection purposes and also for denture marking in care homes. As part of their system, the company, "Dentident" offers an initial start-up kit comprising a microchip reader, 20 microchips, and an annual registration to a national database. The database purports to positively identify the practitioner and/or the denture manufacturer, hence details can only be accessed by authorized personnel (23). At present, however, there is insufficient longitudinal data pertaining to its long-term performance with which to form a definitive opinion of the device's effectiveness, nevertheless, the results so far appear very encouraging.

Acknowledgments

Dr. I.A. Pretty is funded by a Clinician Scientist Award from the National Institute for Health for Health Research (U.K.).

References

1. Dippenaar AP. Denture marking: an aesthetic inclusion technique. J Dent Assoc S Afr 1986;41(1):13.
2. Bengtsson A, Olsson T. Frequency of edentulism and identification marking of removable dentures in long-term care units. J Oral Rehabil 1996;23(8):520–3.
3. Richmond R, Pretty IA. Contemporary methods of labeling dental prostheses—a review of the literature. J Forensic Sci 2006;51(5):1120–6.
4. Merlati G, Danesino P. Observations on dental prostheses and restorations subjected to high temperatures: experimental studies to aid identification processes. J Forensic Odontostomatol 2002;20(2):17–24.
5. Murray CA, Boyd PT, Young BC, Dhar S, Dickinson M, Currie JNW. A survey of denture marking within the United Kingdom. Brit Dent J 2007;203(11):E24;652–3.
6. Reid R. On application of dental science in the direction of crime. Brit Dent J 1884;5:556.
7. Campbell JM. Dentistry then and now. Glasgow: Pickering and Inglis, 1963.
8. Thomas CJ. The role of the denture in identification: a review. J Forensic Odontostomatol 1984;2(1):13–6.
9. Haines DH. Identification in mass disasters from dental prostheses. Int J Forensic Dent 1973;1:11–5.
10. Harvey W. Identity by teeth and the marking of dentures. Brit Dent J 1966;121(7):334–40.
11. Turner CH, Fletcher AM. Denture marking and human identification. Brit Dent J 1976;141(4):114–7.
12. Thomas CJ, Mori T. In search of a suitable denture marker. J Forensic Odontostomatol 1995;13(1):9–13.
13. Luebke RJ. Denture identification: a public service. Iowa Dent J 1985;71(3):31–2.
14. Olsson T, Thureson P. Denture marking. A study of temperature resistance of different metal bands for ID-marking. J Forensic Odontostomatol 1993;11(2):37–44.
15. Ling BC, Nambiar P, Low KS, Lee CK. Copper vapour laser ID labelling on metal dentures and restorations. J Forensic Odontostomatol 2003;21(1):17–22.
16. Combe EC. Notes on dental materials, 6th ed. London: Churchill Livingstone, 1992.
17. Woelfel JB, Paffenbarger GC, Sweeney WT. Some physical properties of organic denture base materials. JADA 1963;67:489–504.
18. Steele J, Treasure E. Total tooth loss in the United Kingdom in 1998 and the implications for the future. Brit Dent J 2000;189:598–603.
19. Harwood L. The evidence base for current practices in prosthodontics. Eur J Prosthodontics Rest Dent 2008;16(1):24–34.
20. Turner CH, Fletcher AM, Ritchie GM. Denture marking and human identification. Br Dent J 1976;141(4):114–7.
21. Vestermark J. Identification from dental disasters. Int J Forensic Dent 1975;3(7):3–6.
22. Richmond R, Pretty IA. Denture marking—patient preference of various methods. J Forensic Sci 2007;52(6):1338–42.
23. DentIDent. http://www.dentident.com.au

Additional information and reprint requests:
Iain A. Pretty, B.D.S.(Hons), M.Sc., Ph.D., M.F.D.S. R.C.S.(Ed)
Dental Health Unit
3A Skelton House, Lloyd Street North
Manchester M15 6SH
United Kingdom
E-mail: iain.pretty@manchester.ac.uk