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Identification of Mass Disaster Victims: The Swiss Identification System

In eleven airplane crashes between 1963 and 1974 there were 1189 victims [*1*]. One hundred sixty-seven victims could not be identified, 331 were identified wholly on the basis of dental evidence, and 166 other cases were identified from dental and other evidence (Table 1). With the standard methods of forensic odontology each victim who had to be identified by comparison of postmortem and antemortem dental records required, on the average, three man-hours just for the postmortem oral examination [*2*]. A complete set of antemortem dental records may take days to reach the identification center, may be incomplete or incorrect, or may not exist at all [*3,4*]. Thus a quicker and more accurate identification procedure for victims of mass disasters remains a goal of forensic science.

Carlsen [*5*] proposed that dentures should contain a metal plate with the name of the dentist and an identification number. Krüger-Monsen [*6*] listed detailed requirements for denture marking that were adopted by the U.S. Air Force School of Aerospace Medicine [*7*]. However, according to Haines [*8*], edentulous people usually constitute only a small portion of the population in mass disasters. Thus the need remains for a reliable forensic identification system universally applicable in natural teeth and dentures [*3*].

A recent proposal calls for the placement of an "information carrier" under a filling in a tooth along with a pin modified with an indentation to make it radiographically unique [*9*]. The forensic odontologist viewing a victim's X-ray films would, in theory, recognize the pin, remove the filling, and retrieve the identification carrier. However, in restorative dentistry there is at this time a wide variety of pins in use, and a small indentation may not represent a sufficiently distinctive signal. Additionally, a system that depends entirely on radiographic findings is incompatible with radiopacities of crowns and extensive restorations. Finally, X-ray equipment, especially the newer portable variety, is not always immediately available to the identification team, and when it does become available the X-ray station is likely to become the bottleneck of the identification procedure [*2*].

It is the purpose of the present report to describe a system that eliminates the necessity for locating antemortem dental records, avoids the delay involved in postmortem X-ray examination, and does not require placing a pin and restoration in the dentin. It permits a rapid and positive identification of victims of mass diasters such as airplane crashes, hotel or nightclub fires, battles, earthquakes, floods, or mass exterminations. Minimal additional training is required for the forensic personnel.

The Swiss Identification System

Central to the Swiss identification system[2] is an encoded information chip sealed within the enamel of the tooth with a fire-resistant filling of red composite material (Fig. 1). The red

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[2]i.dent.®

TABLE 1—*Methods used to identify victims of airplane crashes reported 1963-1974.*

Authors[a]	Victims	Dental Identification Alone	Dental Identification and Other Methods	Nondental Methods	Unidentified Victims
Haines, 1967	72	34	6	32	0
Keiser-Nielsen, 1963	42	10	18	14	0
Keiser-Nielsen, 1963	101	0	45	0	56
Salley, 1963	127	62	0	65	0
Stevens, 1966	218	21	0	197	0
Wyk, 1969	122	6	25	80	11
Peterson, 1971	109	53	0	35	21
Ashley, 1972	162	70	0	81	11
Ashley, 1972	64	10	0	4	50
Waaler, 1972	24	6	9	9	0
Beckmann, 1974	148	59	63	8	18
Total	1189	331	166	525	167

[a]Cited in Ref *1*.

color insures the rapid location of the information chip at the disaster site identification center.

A microprocessing unit allows an operator, using a typewriter keyboard (Fig. 2),

(1) to place in its memory 13 alphanumeric characters such as a social security number;
(2) to make corrections in memory;
(3) to order an electromechanical engraver to print the information from memory by indentation onto a gold disk; and
(4) to cause the chip to be ejected from the engraver.

The characters, engraved as a series of dots, are easily read with the aid of an ×8 hand lens. The gold disk[3] has a diameter of 2.0 mm and a thickness of 0.25 mm (Fig. 3). Because of its melting range, between 1360 to 1480°C, it can resist temperatures higher than those used for cremation of human remains.

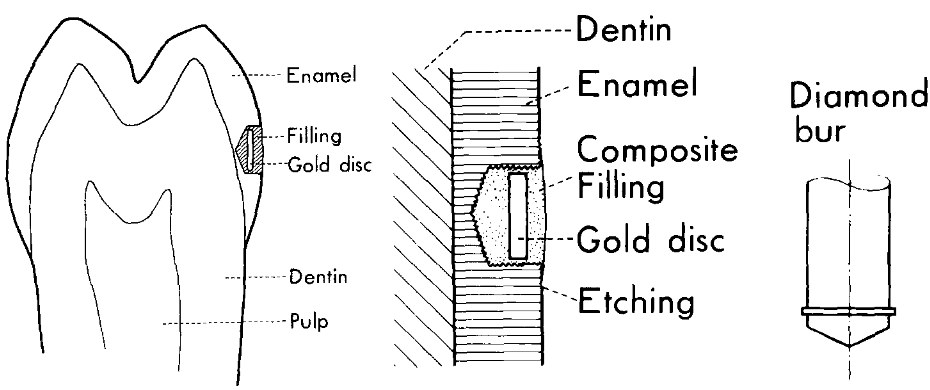

FIG. 1—(left) *Buccolingual section of a tooth with the identification chip in situ;* (middle) *detail of identification chip placement; and* (right) *diamond burr for cavity preparation.*

[3]Ceramicor Cendres et Metaux, 2500 Biel, Switzerland.

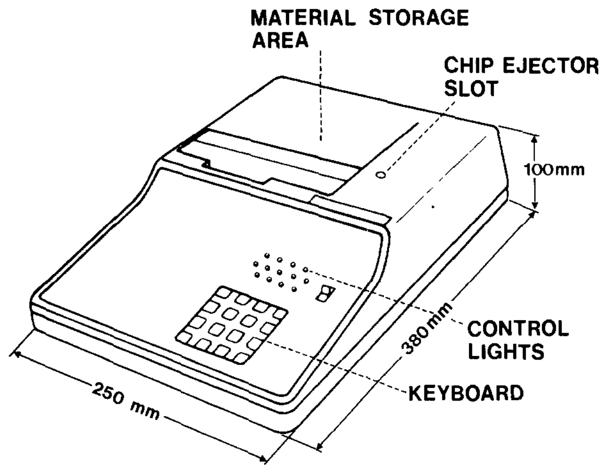

FIG. 2—*Microprocessing unit, keyboard, and engraver.*

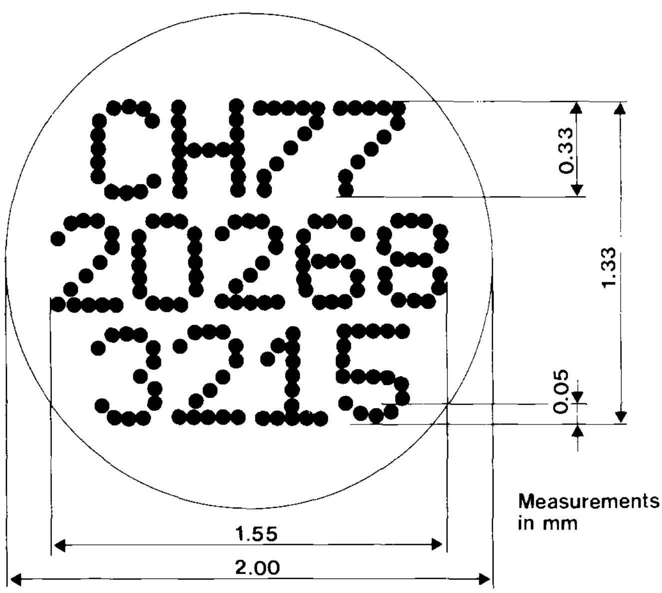

FIG. 3—*Identification chip: encoded gold disk.*

The chip is sealed in a cavity prepared within the lingual enamel of the selected tooth with a red composite material filling and the acid-etch technique. For the preparation of the cavity a standardized self-limiting diamond burr[4] (Fig. 1) was developed to be used in the high-speed dental handpiece.

Based on previous investigations in this department [*10*] it was deemed necessary to test, under stress conditions, the effects of the inclusion of the gold disk within the body of conventional composite filling materials on the qualities of the marginal seal. In spite of the growing importance of dental identification of disaster victims a review of the literature reveals a surprising dearth of experimental data on the effects of heat and fire on the oral

[4]Intensiv Swiss Dental Diamond, 6900 Cassarate, Switzerland.

structures. References to the thermal effects of fire on the dentition and prostheses are for the most part incidental findings, supported by clinical impressions alone.

In testing the effects of heat and fire on dental restorations by placing teeth in a ceramic oven it was soon apparent that they would fracture and carbonize at relatively low temperatures, in agreement with the reported susceptibility of maxillary anterior teeth. However, the exposure to heat in an oven is inadequate for posterior teeth, which are very durable in fire accidents, the tongue and cheeks insulating them as well as posterior parts of dentures from the sudden direct effects of heat [*11-13*]. Without actually incinerating cadaver material no adequate experimental model can be offered for testing the heat-protective properties of the investing soft tissues. Ignoring the effects of the soft tissues, we studied the color changes of enamel, dentin, and colored composite fillings exposed to fire under controlled conditions of direction, temperature, and time.

Experimental Procedure

Laboratory investigations were concerned with (1) a study of the micromorphological characteristics of the marginal seal of fillings made with red composite material subjected to ultrasonic treatment or thermal cycling and (2) a study of the color changes of the crowns of teeth and of the red composite filling exposed to heat.

Ultrasonic Treatment and Thermal Cycling of Test Fillings

Test cavities in the lingual enamel of twelve recently extracted human molars were prepared with the self-limiting burr, and the enamel was etched. Identification chips were placed inside the cavities which were then filled with red composite material. The teeth were stored under water at room temperature. The adhesive restoration was finished and polished as previously described [*10*]. Replicas[5] of the teeth were made, and epoxy dies were prepared and vacuum-coated with gold for scanning electron microscopy.

Half of the teeth were treated for 30 min in an ultrasonic water bath[6] containing 2 litres of water. During the course of the test the water temperature rose from 16 to 25°C.

The remaining six teeth were subjected to thermal cycling. They were placed for 60 s each in two waterbaths, one at 2°C and the other at 60°C. It took 5 s at room temperature (20°C) to move the teeth from one bath to the other. Each tooth was in each bath 100 times.

Replicas were again made of the test teeth, and in a blind procedure both sets of replicas were examined under the scanning electron microscope. Each arc segment of the margins of the adhesive filling was examined and scored by using the following quality criteria of the marginal area:

(1) gap,
(2) underfilled cavity,
(3) overfilled cavity, and
(4) perfect margin.

For each test filling the total length of the margin in a given category was expressed as a percentage of the total length of all margins. The results are given in Tables 2 and 3.

Color Changes

To examine the color changes of teeth and of three different formulations of composite materials, test cavities were prepared in the buccal enamel of 54 single-rooted teeth. The

[5]Xantropene Blue, Bayer, 5090 Leverkusen, Germany.
[6]Brandsonic 220 V, Bender & Holbein, 8006 Zurich, Switzerland.

TABLE 2—*Micromorphological characteristics of cavity margins before and after ultrasonic treatment. Results expressed as percentages of total length of six margins:* G = *gaps,* U = *underfilled cavity,* O = *overfilled cavity, and* P = *perfect margin.*

	Before Ultrasonic Treatment				After Ultrasonic Treatment			
Tooth	G	U	O	P	G	U	O	P
1	0	12.5	0	4.2	0	12.5	0	4.2
2	0.5	8.8	1.3	6.0	0.5	10.2	0	6.5
3	0	10.5	0	6.5	0.5	12.3	0	3.7
4	0	13.6	0	3.1	0	14.1	0	2.5
5	0.4	9.7	0	6.5	0.2	11.1	0	5.1
6	0	5.3	0	11.1	0	11.3	0	5.3
Total	0.9	60.4	1.3	37.4	1.2	71.5	0	27.3

TABLE 3—*Micromorphological characteristics of cavity margins before and after thermal cycling. Results expressed as percentages of total length of six margins;* G = *gaps,* U = *underfilled cavity,* O = *overfilled cavity, and* P = *perfect margin.*

	Before Thermal Cycling				After Thermal Cycling			
Tooth	G	U	O	P	G	U	O	P
1	0	13.4	0	3.2	0	13.4	0	3.2
2	0	11.6	0.5	4.6	0	13.2	0	3.5
3	0	11.6	0.5	4.6	0	15.3	0	1.4
4	3.4	9.3	0	3.9	2.0	13.0	0	1.6
5	0	6.9	1.9	7.9	3.5	8.3	0	4.9
6	0	9.5	0	7.2	1.4	8.1	0.5	6.7
Total	3.4	62.3	2.9	31.4	6.9	71.3	0.5	21.3

teeth were then divided at random into three groups of 18 each. In one group the test cavities were filled with a composite material containing colored glass filler.[7] In a second group the cavities were filled with a mixture of a commercial two-paste composite system and an inorganic red stain. The third group received a mixture of commercial composite material, titanium oxide, and red tattooing dye.[8] In neither of the last two cases did the additions constitute more than 10% of the composite material by weight. The fillings were finished, polished, and stored at room temperature (20°C) under water until used.

The teeth were placed in groups of three with their roots in investment plaster that was allowed to harden. Each type of filling was positioned at the middle, right, and left to eliminate the chance of position affecting the results.

Color transparencies were made of each block, buccal and lingual. The block of three teeth was then exposed for 1 min on the lingual side to the heat from two torches burning a mixture of compressed air and natural gas. The temperature was 350°C as monitored by a digital thermometer.[9] The transparencies were repeated. At the end of the complete sequence of blocks the temperature was raised stepwise by 50°C, the treatment and transparencies being repeated, until a temperature of 550°C was reached. From the color transparencies made after treatments at 350, 500, and 550°C, each filling in a block of three was assigned by a panel of ten dentists to one of three contrast categories: (1) best detectability, (2) worst detectability, and (3) intermediate detectability.

[7] Provided by Kulzer & Co. GmbH, D-6382 Friedrichsdorf, Germany.
[8] Tatoo Dye®, Almore Manufacturing Co., Portland, Ore.
[9] Digitherm mKII, Kane-May Instrumentation, England.

Results

The frequency distribution of underfilled and overfilled cavities before ultrasonic treatment and thermal cycling was similar to that reported in previous investigations of composite fillings from this laboratory [*14*]. Both ultrasonic treatment and thermal cycling had the tendency to increase the length of marginal gaps; however, the increases were not significant.

The color of the composite fillings was still clearly detectable even after the nonfilled side of the teeth had been exposed to temperatures up to 500°C. At this level the first splinters of enamel directly exposed to flame were lost and darkening of the underlying dentin became widespread. After 1 min at 550°C the underlying dentin darkened further and the enamel was almost completely splintered off from the side facing the flame. These observations are in agreement with those of other investigators [*15*]. On the filling side, however, the enamel remained intact though the underlying dentin had become darker. The major change at 550°C was the loss of color from most of the filling composite materials. The filling with titanium oxide and tattoo dye became lighter and contrasted less with the environmental enamel. The other two types of fillings became darker but remained easily detectable. The filling most persistently maintaining its initial color was the composite with the colored glass filler (Table 4).

Discussion

Despite technology and safety consciousness serving to reduce the prevalence of transportation and industrial disasters the chance that any single accident will result in larger numbers of victims seems to be increasing [*16-18*]. Though the development of permanent forensic disaster teams with organizational ability, a multidisciplinary approach, and technological sophistication is necessary and to be encouraged to respond to this increased need, it is clear that there are human, legal, and administrative circumstances that will frustrate the forensic team's ability to examine the disaster scene carefully with the remains in situ. In recent disasters involving record numbers of victims, investigators were faced with the task of identifying remains with little more to work from than bodies in boxes and bags [*16,17*].

The reports of the same recent disasters [*17,18*] serve to reemphasize the importance of teeth and dentures because of their ability to resist the destructive forces associated with

TABLE 4—*Detectability of stained composite fillings exposed to increasing temperatures:* B = *best,* I = *intermediate, and* W = *worst detectability. Raw scores (in parentheses) expressed as a percentage of total number of responses possible in a category by ten dentists examining 18 transparencies of the fillings at each temperature level (10 × 18 = 100%).*

	Staining Material in Composite Fillings								
	Inorganic Red Stain			Titanium Oxide and Red Tattooing Dye			Colored Glass		
Temperature, °C	B	I	W	B	I	W	B	I	W
350	60.5	34.0	5.5	0.0	20.0	80.0	39.0	47.0	14.0
	(109)	(61)	(10)	(0)	(36)	(144)	(70)	(85)	(25)
500	30.5	55.5	14.0	0.5	15.0	84.5	69.0	29.5	1.5
	(55)	(100)	(25)	(1)	(27)	(152)	(124)	(53)	(3)
550	34.5	52.0	13.0	6.5	11.0	82.5	55.5	37.0	2.5
	(62)	(94)	(24)	(11)	(20)	(149)	(107)	(68)	(5)
Total	42.0	47.0	11.0	2.0	15.5	82.5	55.5	38.0	6.0
	(226)	(255)	(59)	(12)	(83)	(445)	(301)	(206)	(33)

mass disasters and to encourage their acceptance as both primary and corroborative evidence in victim identification. Also, because of their easy accessibility, they are increasingly being regarded as possible information carriers. The Swiss identification system allows a forensic investigator to positively identify a victim even if the remains are so badly burned or decomposed as to make conventional identification methods based on fingerprints, jewelry, personal effects, and clothing impossible. As long as the tooth exists the identification chip can be recovered. The system does not depend on locating a complete set of antemortem dental records as is the case with identification work by comparison. The colored composite and fire-resistant filling signals the location of the identification chip to the forensic investigator who can, without cumbersome equipment, recover the chip in a much shorter time than the 3 h needed to perform the average postmortem oral examination. Though the system is based on visual detection of the red composite filling a radiographically distinctive disk fully compatible with the present system is currently being investigated.

To insure the safety of the identification chip and the visibility of the stained filling and to maintain dental esthetics, the lingual surface of a molar, in natural or artificial teeth, is proposed as the preferred site for insertion of the identification chip (Fig. 4).

The coding of the gold identification disk with the engraver is possible within a minute.

The cavity preparation and the insertion and sealing of the chip can be done by a dentist without additional special training. Technical requirements are a standardized burr and a composite material containing the red glass filler. The person receives the identification chip in a single 15- to 30-min dental appointment.

The results of in-vitro tests suggest that the composite filling and identification chip are resistant to various types of destructive forces associated with airplane crashes, hotel or nightclub fires, battles, earthquakes, floods, or mass exterminations. Investigators, once informed of the existence of the identification system, can detect and recover the chip from the victim's tooth and read it with a simple ×8 hand lens.

As a final note, it is obviously possible to use the same system to identify valuable objects

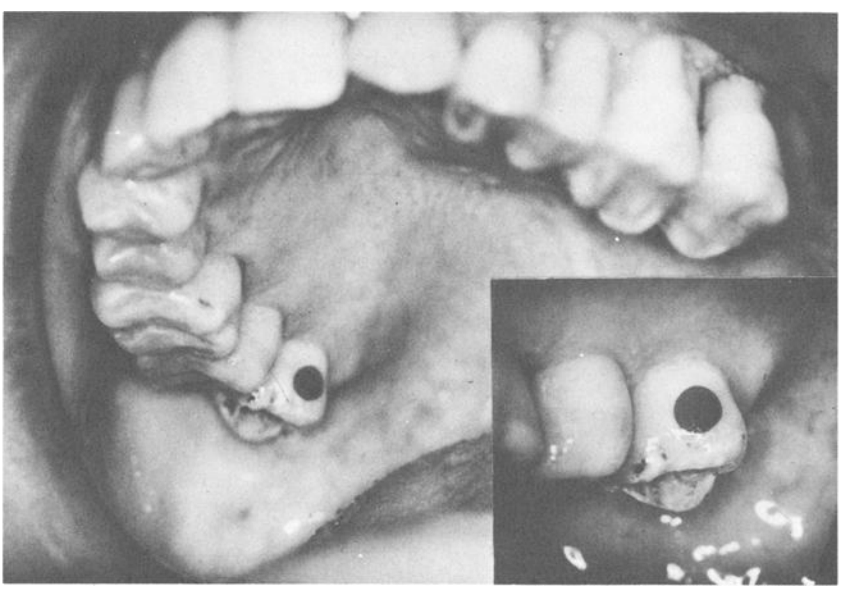

FIG. 4—*Photograph and enlargement of maxillary right third molar with disk and filling in place (the contrast is accentuated in black and white reproduction).*

such as jewelry, art objects, and car and boat engines. The sealant and identification chip material would be specifically selected for each case.

Summary

A new, simple, and reliable forensic identification system has been described. It permits the rapid and positive identification of victims of catastrophies such as airplane accidents, battles, floods, and fires. An electronic microprocessing unit directs a mechanical engraver to encode up to 13 alphanumeric characters on a small gold disk 0.25 mm thick and 2.0 mm in diameter. The identification chip is sealed in a 0.8-mm deep cavity prepared with a specially designed diamond burr in the lingual enamel of a molar tooth. The sealant is a stained composite material shown experimentally to be leakage proof, fire resistant, and readily detectable in teeth exposed to high temperatures. At the identification center the gold disk can easily be recovered and the victim positively identified without recourse to time-consuming comparison of dental records. Minimal training is required for the forensic personnel.

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