Part 2

POSTMORTEM IDENTIFICATION THROUGH MATCHING DENTAL TRAITS WITH POPULATION DATA

Chapter 5
Introduction

Forensic dental identification is a process whereby dental data concerning a person, usually deceased, are gathered and compared with known records of a missing person in order to determine whether the two correspond. The forensic dentist then correlates and weighs the evidence contained in the dental data sets and reaches a conclusion as to the likelihood of a match.

The collation, comparison and presentation of dental evidence and the ability to give an expert opinion as to its significance in an individual case has been successfully demonstrated and reported in all western jurisdictions in relation to incidents ranging from single deaths to large scale disasters involving hundreds of fatalities.

Despite the acceptance of this process by coroners and juries for at least 50 years, no large study has reported on the prevalence of any of the multitude of standard restorative procedures, which may characterise individual teeth.

Yet it is often upon the restorative configuration of individual teeth that the forensic dentist bases most, if not all of the case, for matching and thus identification of a person. Forensic dentists work with the conviction that by demonstrating a number of correlations between the recorded restorative status of an individual and that of an unknown corpse, a match is declared as possible, likely or highly likely, depending on a somewhat arbitrary number of matching points and a subjective evaluation.

Forensic dentists, and others, have long advocated the need to determine the prevalence of restorative and other dental traits (Dahlberg , 1957; Gustafson, Johanson, 1963; Keiser-Nielsen, 1970; MacFarlane, MacDonald, Sutherland, 1974; Keiser-Nielsen, 1977; Jerman, 1981; Phillips, 1983; Fellingham, Kotze, Nash, 1984; Hill, 1989; Moenssens, 1993; Andersen, Juhl, Solheim, Borrman, 1995; The Queen v Terrence James Mitchell 1997; Solheim, Schuller, 1999). Importantly, details of tooth-based and tooth-surface-based restorative status, and the prevalence of missing teeth, is of fundamental relevance to forensic dental identification.

Hypothesis

The configuration of the dental tissues and dental restorative features are individually unique, therefore detailed dental records may be used as personal identification markers.

The Research Question

The purpose of the study was to investigate the research question: to what extent would data on the distribution and prevalence of restoration types in the human dentition facilitate forensic identification?

Objectives

1. To develop a system for recording detailed dental data obtained from population samples.

2. To establish a database of dental data obtained from population samples. These data will be classified according to population and dental (including restorative) characteristics and hence will enable the construction of profiles that may be defined by selected combinations of population and dental characteristics.

3. To demonstrate that, given a human dental specimen, it is possible to calculate the probability (with reference to the database) that the configuration of dental data, unique to that specimen, match the configuration of an assumed corresponding record, and hence determine the identity of the human from whom the specimen originated.

4. To apply this method in forensic cases to make postmortem identification.

Chapter 6

A new system for establishing a reference database of dental characteristics for use in forensic dental investigations

6.1 FileMaker Pro 4.0* software

FileMaker Pro 4.0 is a software program designed for creating an electronic database. Once information is entered into it, functions can be invoked to process the information in ways that allow for simple or complex presentations and analyses of the data.

Of the many software packages available for ordering related fields of data, FileMaker Pro 4.0 was chosen for this study due to its ability to allow the creation of highly visual customised data entry forms and its rapid information processing capabilities. Importantly, FileMaker Pro 4.0 operates

* FileMaker Inc.Corporate Headquarters, 5201 Patrick Henry Drive Santa Clara, California, USA

ϕ Apple Computer Inc, 1 Infinite Loop Cupertino, California, USA

on either Macintosh[ϕ] or Windows[Ψ] operating systems and allows the direct transfer of programs between the two systems.

6.2 Database entry screen

In designing an entry screen for data, it was decided that a form which was visually similar to a dental chart odontogram would facilitate the accurate transcription of data into the computer. Each Database Entry Screen (Figure 6.1) represents a single patient's full dental charting. This screen allows the entirety of a single patient record to be viewed at a glance.

[Ψ] Microsoft Corporation, Redmond, Washington, USA

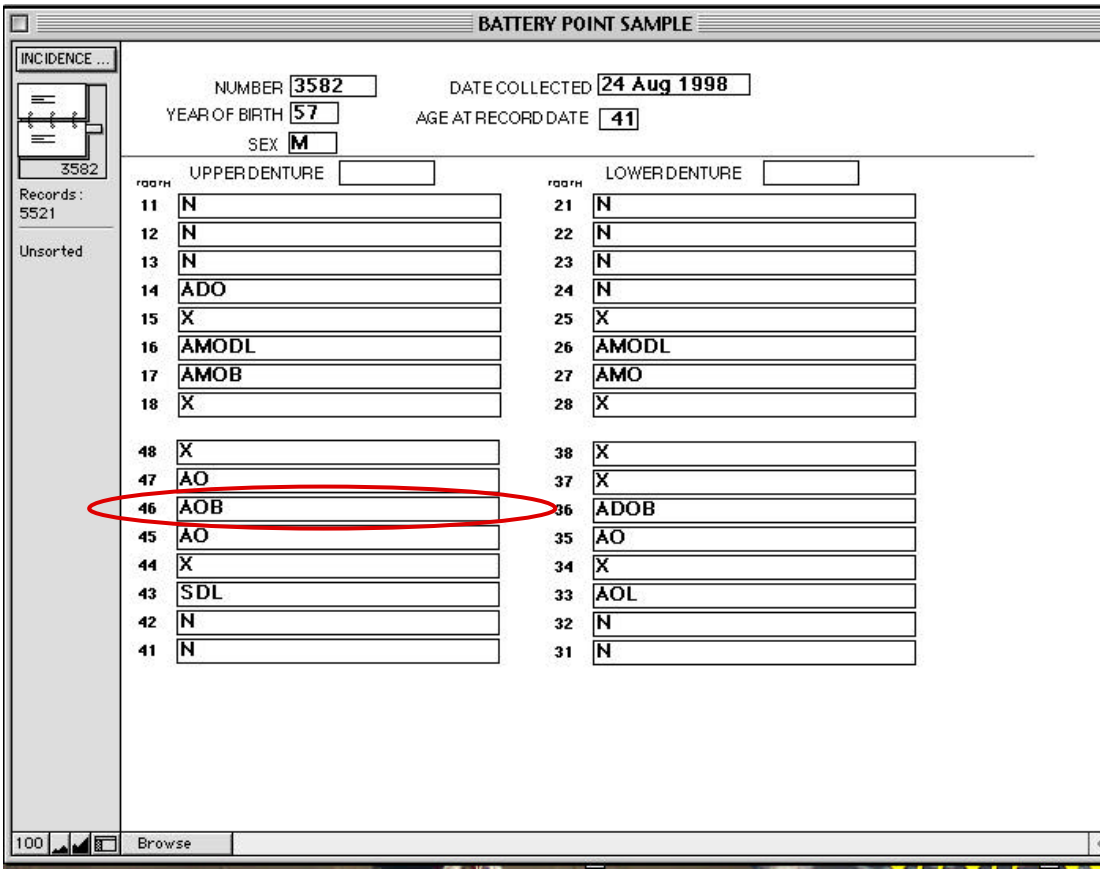


Figure 6.1 Database Entry Screen & Data Fields (codes: see p50)

6.3 Records and data fields

The entire database is made up of thousands of individual records. Each record, that is, the entire set of items belonging to one individual, is composed of fields. Each field contains information relating to specified

attributes such as age and sex. There are 32 fields relating to each of the permanent teeth, divided into four quadrants. In Figure 6.1, the field representing tooth 46 is circled in red.

The four quadrants of tooth data fields contain the dental status codes (see Table 6.1 for interpretation). Note that each tooth field may contain one or more data codes.

Because each tooth field needs to contain information on each restoration and other traits, the individual data is entered using the appropriate code (Table 6.1) and a comma separates each data item. This allows the compiling functions of the database to find and separate individual traits from the text characters. Tooth data fields with comma-separated data are illustrated in Figure 6.4 (tooth data fields 44, 45, 47 and 35).

Table 6.1 Tooth data codes

SURFACE CODE	
M - mesial, D - distal, O - occlusal, B - buccal or labial, L - lingual or palatal	
CODE	**TOOTH STATUS**

N	present , untreated - no caries
X UE	missing tooth unerupted tooth - over age 15 years
RR	retained root - at gum level or sub mucosal
Z	caries
A	amalgam
S	synthetic - composite or glass ionomer
G	gold
PJC, PBM	porcelain jacket crown, porcelain bonded to metal
P PV	bridge pontic porcelain veneer
CRG, CRSS	gold crown, stainless steel crown
CRA	amalgam crown
CRC	composite crown
FS	fissure seal
RCT	root canal treated
DEC	retained deciduous tooth - over age 15 years
FU or FL PUC, PLC	full upper denture, full lower denture partial upper chrome denture, partial lower chrome denture
PUA, PLA	partial upper acrylic denture, partial lower acrylic denture (partial dentures - state number of teeth - eg PUC6)

6.4 Data viewing screens

The FileMaker Pro 4.0 program has many useful functions. For example, existing screen formats may be rearranged to show the fields in different configurations.

Two formats were created so that data could be collated and viewed in different ways:

1. The Database Entry Screen format as shown in Figure 6.1 is used to enter and check data in relation to one record or for viewing the results of a set of records with a particular attribute, for example subjects born in a specific year or period.
2. The Single Line Viewing Screen shown in Figure 6.2 illustrates the second display format in which several records may be viewed at once. The single line means that the fields are strung along a line. In this case, the screen must be scrolled to see all the fields.

This view (Figure 6.2) is useful for comparing a group of selected records. Through the use of the SORT function, records can be sorted to appear in a prescribed order, for example, in year of birth or in gender groups.

Figure 6.2 Data screen illustrating the single line view of several records, ID 5495 to ID 5521

6.5 The FIND function

FileMaker Pro 4.0 allows for a comprehensive examination of the database by means of the FIND function. The FIND function allows for the

rapid location of a particular record or set of records that possess a particular data characteristic.

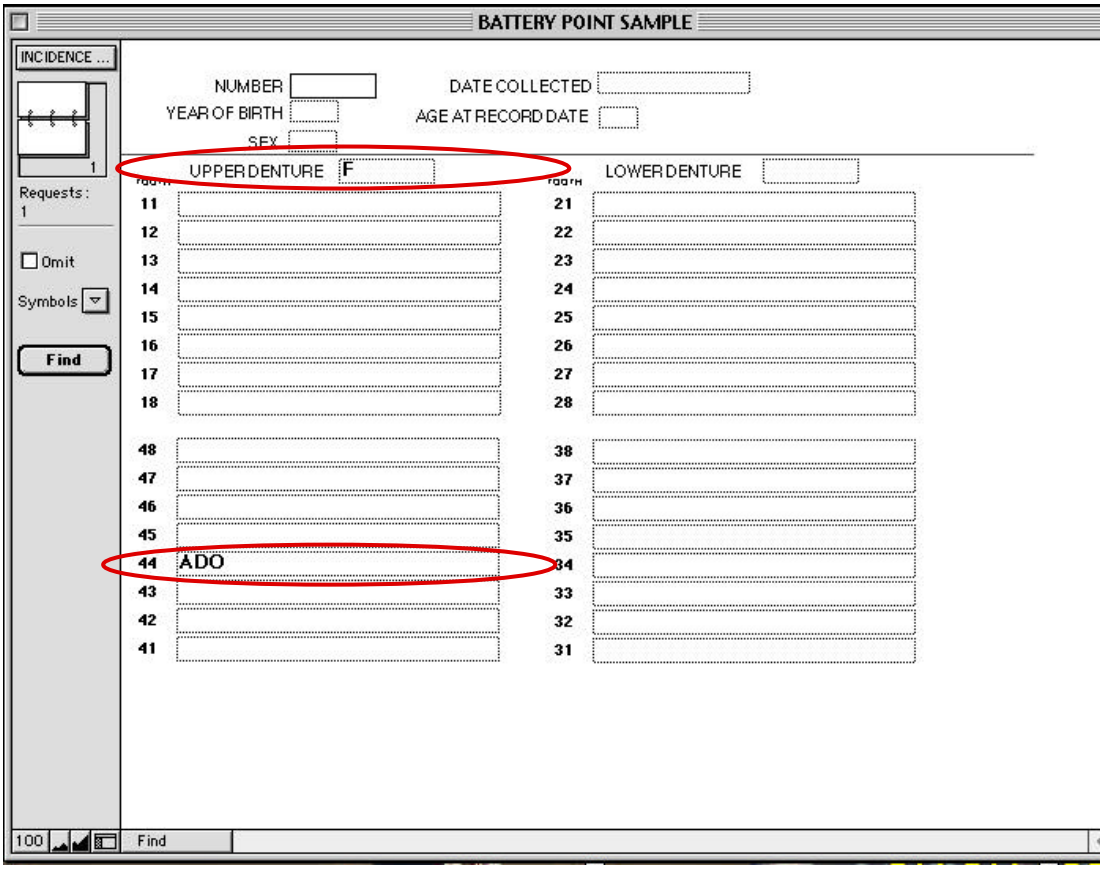


Figure 6.3 An illustration of the use of the FIND function

When the FIND function is invoked, a blank data entry screen appears. On this blank screen, F (upper denture) has been entered into the upper-denture field and ADO (an amalgam disto-occlusal) has been entered into the tooth 44 field (Figure 6.3). When the FIND button is activated, only

those records that contain these codes are found and displayed (Figure 6.4). The result shows that there are 21 records out of the total 5521 with these criteria. In Figure 6.4, record number 8 of the 21 found records is displayed.

The FIND can be even more specific by restricting the search to a particular age or age range, gender or other particular dental trait(s).

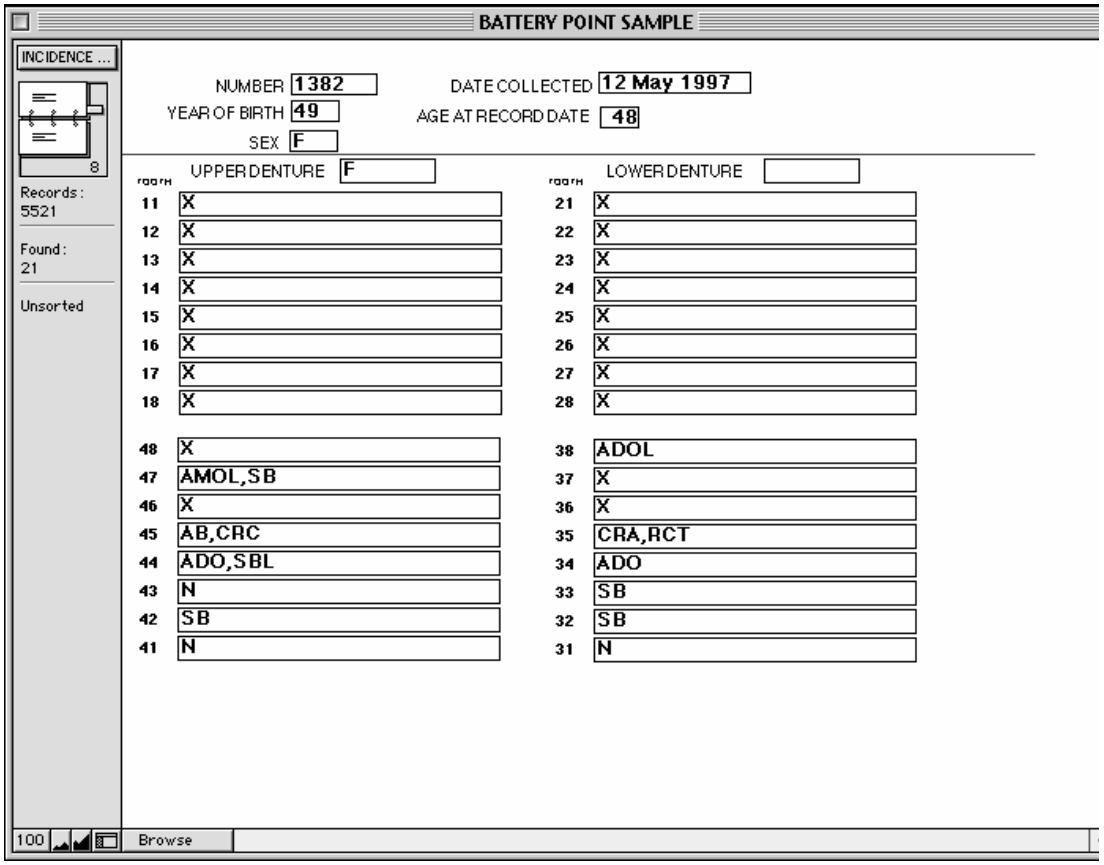


Figure 6.4 Result of FIND function

Thus by consulting the database using the FIND function, any combination of individual or multiple traits in the total sample may be assembled.

6.6 Complex data analysis scripts

It is also possible to write programs for complex specifications, for example, to write a program function that would identify all records containing, say, only five teeth (see Appendix 1 for a more detailed explanation).

Chapter 7

The reference database of dental characteristics

7.1 The study population

For the purpose of illustrating this new system for establishing a database, data collected from dental patients at the author's Battery Point practice are used. Battery Point is a small suburb on the southeastern fringe of the Hobart central business district. Like many Hobart inner suburbs, Battery Point's residents cover a variety of socio-economic groups. However, due to the high property values (amongst the highest in Tasmania) and the proximity to Sullivan's Cove which is the cultural,

arts and restaurant centre of Hobart there is, consequently, a significant number of professional and high income households in the area.

The Battery Point practice draws its patient base principally from the local area, the city and the adjoining waterside suburb of Sandy Bay, which includes the Wrest Point Casino, the University of Tasmania and yacht marinas. These suburbs have the highest income producing households in Hobart (Australian Bureau of Statistics (ABS), 1998).

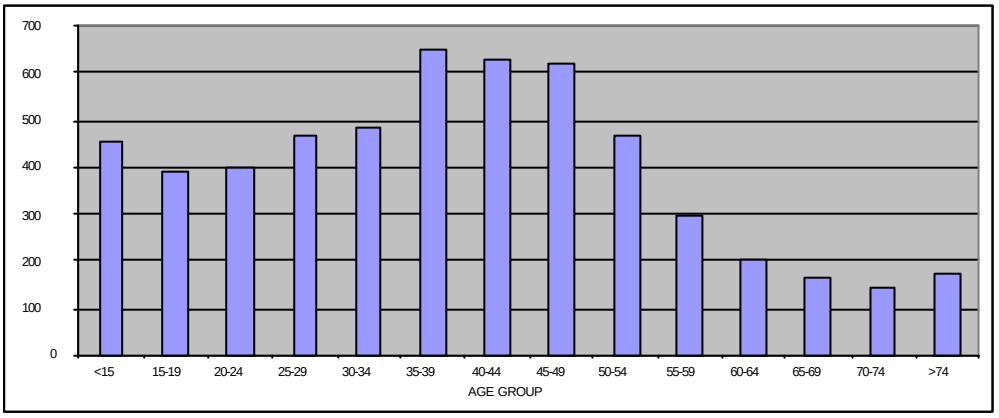


Figure 7.1 Number in each age group - Battery Point sample

A comparison of the age distribution of the sample (Figures 7.1 & 7.2) with that of the general Australian population (Figure 7.4) (ABS, 1998) showed a lower number of people aged under 30 years in the Battery Point sample.

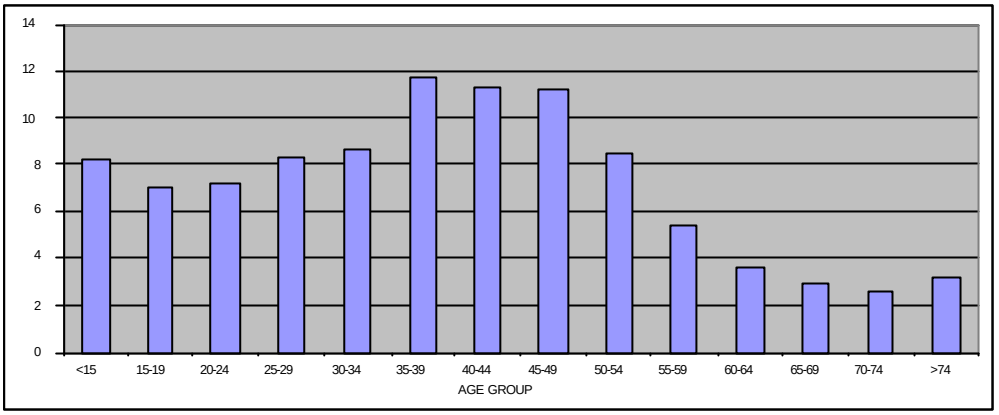


Figure 7.2 Percentage in each age group - Battery Point sample

Australia has 43.0% of the population in this age group and Tasmania has 42.3% (Figure 7.3), while the Battery Point sample has only 30.9%. The fact that more than 80% of Tasmanian school children are treated in Government dental clinics and not in private dental practice clinics may account for the difference.

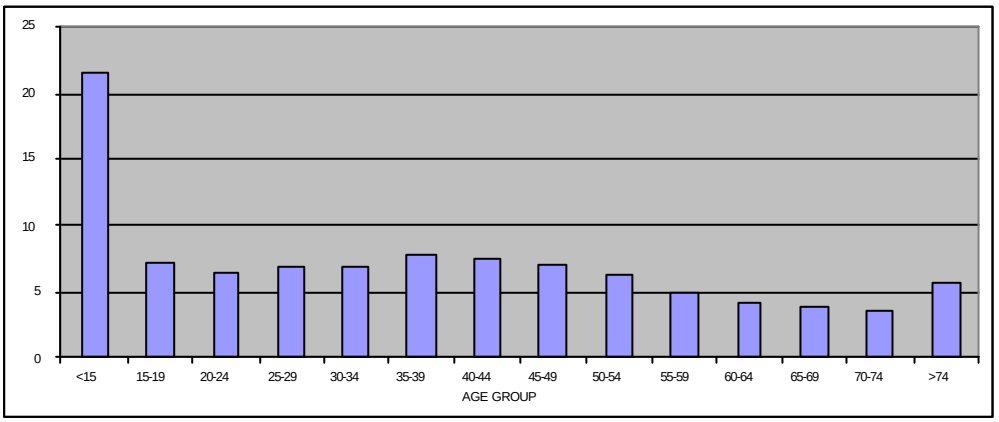


Figure 7.3 Percentage in each age group - Tasmanian population (ABS, 1998)

The Australian population has 36.1% in the 30 - 54 years age-group and Tasmania has 35.5%, while the sample has 51.5%. This is a marked difference and may reflect the nature of the private dentist-attending population as compared with the general population. Females represented 56.4% of the sample showing a significant gender bias in the dentist-attending population.

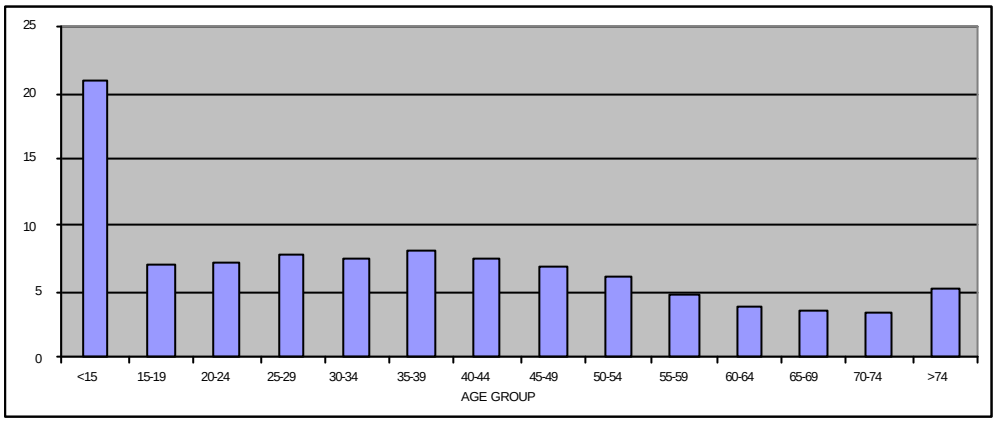


Figure 7.4 Percentage in each age group - Australian population (ABS, 1998)

7.2 Sample selection

At the commencement of this project the author followed a policy that all patients at his Battery Point practice, including children aged 7 years and over, examined at recall or as new patients were included in the sample. A small number of patients from whom year of birth was not obtained were excluded.

During the period August 1996 to August 2001, records of 5521 patients were entered into the database. The distribution of this sample is shown in Figure 7.1.

7.3 Data collection

The data recorded included a full mouth charting of all existing teeth including their restoration and dental caries status, missing teeth, and a detailed description of dentures. Details of all variables recorded are shown in Table 7.1.

The collection of detailed and accurate research data as part of the routine work in a busy dental practice required a time-efficient and unambiguous data collection method. The dentists and auxiliary staff were briefed in the principles and goals of the survey and a standardised format and coding system (Table 6.1) were devised for use by everyone.

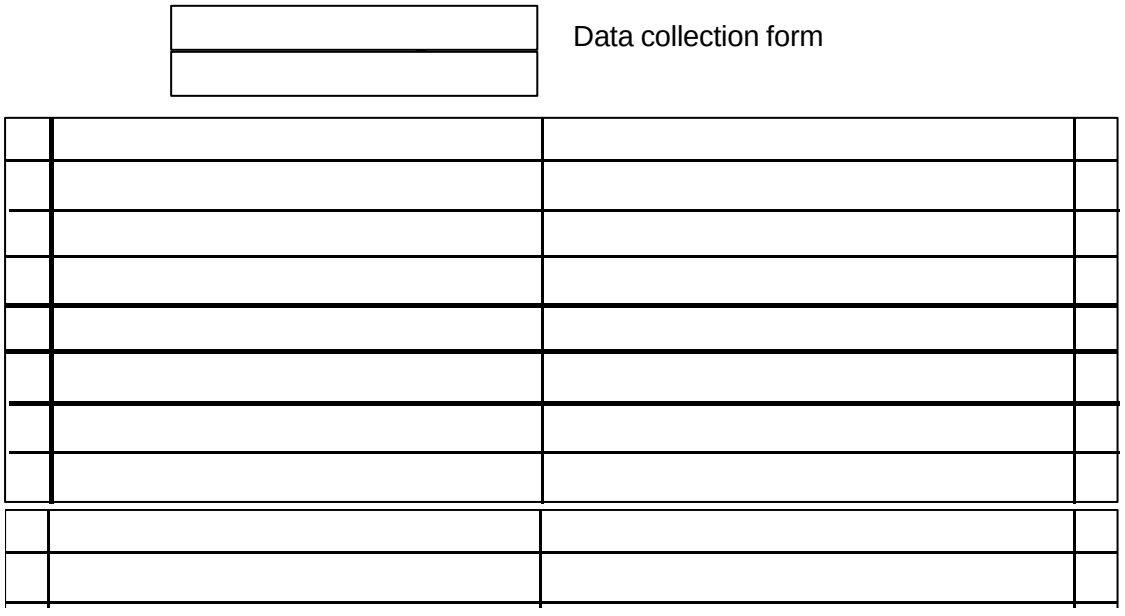
Table 7.1 Data fields and data collected

Date of collection of data
Year of birth
Gender
Upper removable prosthesis (denture type and number of teeth)
Lower removable prosthesis (denture type and number of teeth)

32 individual tooth fields, each containing:

- Restorative material type: amalgam, synthetic, porcelain or gold.
- Surfaces on which that material appears: mesial, distal, buccal, lingual or occlusal (ie front, back, outside, inside or top).
- Whether tooth is missing.
- Whether tooth has caries and on which surfaces.
- Root fragment from a missing tooth.
- State of eruption of a tooth (if part-erupted).
- Presence of bridge pontic in a missing tooth space.

The odontograms used in the practice are set up with the tooth surfaces diagrammatically depicted in a square and set out in the Zsigmondy / Palmer configuration, with teeth annotated in FDI two-digit nomenclature. The requisite detailed charting was marked permanently on the patient chart odontogram. At day's end, the auxiliary staff would transcribe all the charted data on each examined patient from the practice chart to the data collection form (Figure 7.5).



practice record so that entry of any individual into the database would occur only once.

The data collection form was designed to allow the quick and accurate transcription of data by the auxiliary staff. The form is in the same configuration as the Interpol Disaster Victim Identification (DVI) antemortem and postmortem forms incorporating the FDI two-digit tooth numbering system and visually set out in Zsigmondy / Palmer configuration, similar to the practice chart.

The data collection forms were checked each day and then entered into the database by the author. Any discrepancies or irrational entries noted were compared with the original chart and the dentist asked for clarification if necessary, or the patient re-examined. Thus, on a daily basis, commencing in August 1996, the practice records were entered into the database.

7.4 The data set

An enormous data set was assembled containing information on 5521 individuals. For summary purposes, the data could be distributed in many ways. For analysis purposes, the data is inspected in a manner that reflects a specific enquiry. However, there seems to be no particular

distribution that best illustrates the characteristics of the entire data set. A set of tables is provided in the appendix that summarises tooth-specific conditions. These tables serve to illustrate the dimensions of the data set and the possibilities that exist for searches of combinations of features that might correspond to questions raised in a forensic case. Tables referring to denture type frequency and retained deciduous teeth are also included.

Chapter 8

Method of establishing identification

In forensic identification work, two separate situations have to be dealt with. Firstly, the case where a body is found and circumstances lead the police to suspect a known missing person, and secondly, the case where a body is found but there are no clues as to the possible identity.

8.1 Procedure for matching remains with a known missing person.

A typical situation is where remains have been retrieved and taken to a mortuary for postmortem examination. The usual procedure is as follows:

1. Forensic dental examination and charting of the remains.
2. Police investigation of the circumstances of the death which often will focus on a person (or persons) of interest, that is, a known missing person where circumstances indicate some possibility that the remains and this person may be one and the same.
3. Obtaining the dental records (traits) of person(s) of interest.
4. Comparison of remains and dental records and matching.
5. Evaluation of a match. In relation to each remains-specific trait of interest, the prevalence of that trait, as it exists in the database, is calculated.
6. Testing the match.

8.2 Evaluation of a match

The evaluation of a match entails the calculation of trait prevalences, which are then used in a test procedure:

1. Calculation of trait prevalences.

Through the use the FIND function in FileMaker Pro 4.0, the number of occurrences of a particular trait within the whole sample can quickly be found (6.5 FIND function). The number of trait occurrences, divided by the total number of records in the database, gives the prevalence of that particular trait.

2. Testing of match.

The match is tested through the application of the 'product rule', also known as the 'multiplication law', the fourth of Galileo's four Laws of Chance:

> 'Whenever something (such as throwing a die) can have more than one result, the probability of getting any particular combination of results in 2 or more independent trials (whether consecutively or simultaneously) will be the product of their individual probabilities' (Langley, 1970).

For example, the probability of finding any particular combination of traits involves calculating the prevalence of each of the separate matching traits and of multiplying them together in accordance with the product rule. The result, say 0.0000006, is interpreted as follows: There is a match, and the probability of obtaining this match, due to chance alone, is six chances in 10 million, or odds of one in 1,666,666. That is, it is an extremely remote probability that the match is due to chance and, therefore, it is concluded that the match is statistically proven.

On the other hand, if the traits being matched were very common in the database, the outcome of applying the product rule might give a result of, say, 0.6 indicating that the probable error of certifying this match is 6 chances in 10 or 60%. In this case, the match is rejected.

8.3 Procedure for creating a personal profile from unknown remains.

As in the preceding case (8.1), remains have been retrieved and taken to a mortuary for postmortem examination. The sequence of procedures is as follows:

1. Dental examination and charting of the remains.
2. Police investigation of the circumstances of the death does not reveal a link to any known missing person.
3. The forensic odontologist evaluates each remains-specific trait of interest and calculates their prevalence (see calculation of trait prevalences above), which are then compared with known epidemiological and statistical data and, consequently, likely personal characteristics are deduced.
4. The deduced personal profile is provided to police, enabling missing-persons files to be searched for likely persons of interest.

8.4 Demonstration of the method of postmortem identification through matching dental traits with population data

The method may be illustrated in relation to fictitious cases.

8.4.1 Case A

Matching remains with a known missing person.

A woman in her early twenties had been missing for several days. Her friends became concerned, as they last saw her when she refused a lift home with them after attending a club on Saturday night. She had said that she wanted to walk the two kilometres home for exercise. Police were unable to uncover any evidence that she may have herself arranged to disappear and serious concerns were held for her safety. The police, treating the case as abduction, became suspicious of a local man with a criminal history of previous sexual assault.

Ten days later, a body was located by a walker near the edge of a fire track in the vicinity of the missing woman's home. There was physical evidence of rape and murder, and scene examiners found tyre tracks nearby which matched the suspect's vehicle. A man was arrested and charged. Recent events reported to police concerning the missing young woman them to suspect that these were her remains.

There had been considerable media exposure of the case and the police were under public pressure to formally identify the remains as that of the missing

woman so that grieving could commence and undue retention of the body by the coroner would not delay funeral arrangements.

Dental records of the missing woman were quickly located and a detailed dental examination of the remains was performed (Table 8.1). As is typical of young adults nowadays, the number of dental restorations was minimal. There were, however, six units of restorative work described in the dental records for comparison. All of these coincided with the dental status of the remains.

Table 8.1 Dental status of remains compared with dental records of missing woman

MAXILLARY TEETH	REMAINS	DENTAL RECORDS OF MISSING WOMAN
right third molar	partly erupted	
right second molar	unfilled	
right first molar	amalgam occluso-palatal	amalgam occluso-palatal
right second premolar	fissure seal	
right first premolar	unfilled	
right canine	unfilled	
right lateral incisor	unfilled	
right central incisor	fractured crown	synthetic labial
left central incisor	synthetic labial	synthetic labial
left lateral incisor	unfilled	
left canine	unfilled	
left first premolar	unfilled	
left second premolar	unfilled	
left first molar	amalgam occlusal	

left second molar	unfilled	
left third molar	unerupted	
MANDIBULAR TEETH	REMAINS	DENTAL RECORDS OF MISSING WOMAN
left third molar	unerupted	
left second molar	fissure seal	fissure seal
left first molar	fissure seal	fissure seal
left second premolar	unfilled	
left first premolar	unfilled	
left canine	unfilled	
left lateral incisor	unfilled	
left central incisor	unfilled	
right central incisor	unfilled	
right lateral incisor	unfilled	
right canine	unfilled	
right first premolar	unfilled	
right second premolar	unfilled	
right first molar	amalgam occluso-buccal	amalgam occluso-buccal
right second molar	fissure seal	
right third molar	unerupted	

The questions which arise in the mind of the forensic odontologist are (1) how characteristic is this dentition and (2) is the matching of this number of ordinary dental traits sufficient to advise the coroner that it is safe to assume that the remains are indeed those of the missing woman? The prevalence of each of the restorative units was calculated (calculation of trait prevalences in 8.2), the results of which are shown in Table 8.2.

Table 8.2 Prevalence of antemortem dental traits of missing woman

DENTAL TRAIT	PREVALENCE
Prevalence of amalgam occluso-palatal in upper right first molar	243 in 5521 (0.044)

Prevalence of synthetic labial filling in upper left central incisor	148 in 5521 (0.027)
Prevalence of fissure seal in lower left second molar	144 in 5521 (0.026)
Prevalence of fissure seal in lower left first molar	209 in 5521 (0.038)
Prevalence of amalgam occluso-buccal in lower right first molar	196 in 5521 (0.036)

If it is assumed that the individual dental traits described in the antemortem records are independent of each other, the product rule can be applied to determine whether the match was safe. It could be that this particular set of traits was common and could match that found in a significant number of other individuals chosen at random, or it could be that this particular set of traits was very rare and, therefore, highly unlikely to match that of any person chosen at random.

Thus, the probability of obtaining the set of traits according to the product rule is:

$0.044 \times 0.027 \times 0.026 \times 0.038 \times 0.036 = 4.23 \times 10^{-8}$

This probability is equivalent to one in 24 million and, therefore, it is very unlikely that a person chosen at random would exhibit an identical dental configuration of these traits.

The forensic odontologist advises the coroner that the dental status of the remains and that of the missing woman match with a high level of confidence. Accordingly, the coroner allows the body to be released to the family for burial. Six weeks later, the government analyst completes DNA profiling and identity is confirmed.

8.4.1 Case B

Creating a personal profile from unknown remains.

The decomposed and fragmented remains of a person are located in bushland. No mandible is recovered. Police have no information as to the identity of the remains.

The teeth are in good condition. The forensic dentist performs a full charting of the upper jaw (Table 8.3).

Table 8.3 Post mortem charting of victim remains

MAXILLARY TEETH	REMAINS
right third molar	missing antemortem

right second molar	amalgam MOD
right first molar	synthetic MOD
right second premolar	amalgam DO
right first premolar	porcelain fused to metal crown, abutment
right canine	edentulous , bridge pontic
right lateral incisor	porcelain fused to metal crown, abutment
right central incisor	porcelain veneer
left central incisor	porcelain veneer
left lateral incisor	unfilled
left canine	amalgam distolingual
left first premolar	unfilled
left second premolar	unfilled
left first molar	amalgam MODBL
left second molar	synthetic occlusal
left third molar	missing antemortem

Using the FIND function the database shows that the prevalence of unfilled premolars is uncommon in people over 55 years. Amalgam fillings in upper canine teeth are rare in people under 35 years. Amalgam MOD's are very uncommon in people under 35 years. Porcelain veneers on incisors are 8 times more common in females than males. The bridge is much more prevalent in higher socio-economic groups.

The police are provided with a profile (Table 8.4) based on the statistical evidence. Within the files of the Missing Persons Section there is an unsolved case of the disappearance of a corporate director's wife two years previously who was believed to have been kidnapped and held for ransom. She was 42 years-old at the time of her abduction. An unsuccessful ambush by police resulted in the kidnapper breaking off contact and no further demands were made. The woman was not found.

Table 8.4 Victim profile

VICTIM PROFILE
FEMALE AGE RANGE 35 - 55 DENTIST ATTENDER UPPER SOCIO-ECONOMIC GROUP

Acting on the profile provided, police narrowed the search of missing persons' files to three possible cases. The dental records of one missing woman were compared with the remains and a perfect correlation was found. A DNA comparison of the remains with that of the missing woman's son confirmed the dental match.

In this case, the database enabled the creation of a dental profile, which focussed the police search through a large number of recorded missing persons. The distance of the remains recovery site from the abduction point, (140 kilometres), and the time elapsed since the disappearance, may have mitigated against a connection and allowed this case to go unsolved.

Chapter 9

The forensic dental identification of a murder victim

The material in this chapter is concerned with the investigation of a murder in Tasmania, the forensic dental investigation, and the subsequent trial (R v MARLOW & ORS, 2001).

9.1 Discovery of remains

The skeletonised remains of a suspected murder victim were disinterred by police in bushland, near Bellevue Tier in Tasmania's Central Highlands, following information from an informer. The police were aware of three criminals who were strongly implicated in the suspicious disappearance of a person ten years previously. With only hearsay, and no body, the police had not been able to bring charges. However, once this body had been found, the case was re-opened and there was renewed interest in the suspected culprits. The police were planning to take the suspects into custody, but thought that it was unwise to lay charges without proof of identity of the victim. If charges were not laid quickly, news of the finding of the body would reach the suspects, and the police, having no grounds to arrest and hold them, feared

that they would then, in all likelihood, abscond and be difficult to locate again. Rapid identification of the remains was essential.

9.2 Forensic dental examination of remains

Dental records of the suspected victim, Tony Tanner, were located and delivered to the mortuary. The Hobart forensic dentists charted the remains (Table 9.1). The teeth were in good condition. A comparison of the records and the remains showed full concordance. There were no conflicting features, and seven traits were matched. The dental records also included a dental laboratory order card describing the construction of, 'upper denture with 2 front teeth'. There was, however, no denture found with the remains. Thus, a match was achieved in accordance with procedures described in 8.1 above.

Table 9.1 Dental status of remains compared with dental records of Tony Tanner

MAXILLARY TEETH	REMAINS	DENTAL RECORDS OF TONY TANNER
Right Third Molar	partly erupted, caries occlusal	
Right Second Molar	unfilled	
Right First Molar	unfilled	
Right Second Premolar	caries distal	DO restoration required
Right First Premolar	unfilled	
Right Canine	synthetic MODB	one surface synthetic
Right Lateral Incisor	synthetic MO	one surface synthetic
Right Central Incisor	missing antemortem	extracted
Left Central Incisor	missing antemortem	
Left Lateral Incisor	synthetic MOBL	
Left Canine	unfilled	
Left First Premolar	unfilled	
Left Second Premolar	unfilled	
Left First Molar	amalgam occlusal	
Left Second Molar	unfilled	
Left Third Molar	unerupted	

Table 9.1 (continued)

MANDIBULAR TEETH	REMAINS	DENTAL RECORDS OF TONY TANNER
Left Third Molar	unerupted	
Left Second Molar	caries buccal	buccal restoration required
Left First Molar	unfilled	
Left Second Premolar	unfilled	
Left First Premolar	unfilled	
Left Canine	unfilled	
Left Lateral Incisor	unfilled	
Left Central Incisor	unfilled	
Right Central Incisor	unfilled	
Right Lateral Incisor	unfilled	
Right Canine	unfilled	
Right First Premolar	unfilled	
Right Second Premolar	decoronated	
Right First Molar	amalgam occlusal	amalgam occlusal
Right Second Molar	caries buccal	buccal restoration required
Right Third Molar	unerupted	

9.3 Evaluation of the match in the case of Tony Tanner

The prevalence of each of the known antemortem dental traits of Tony Tanner was found by searching the database using the FIND function and applying the calculations shown in Table 9.2.

Thus, the probability of obtaining the set of traits according to the product rule is:

If it is assumed that the individual dental traits described in the antemortem records are independent of each other, the product rule can be applied to

derive the probability of obtaining this set of seven traits. The probability obtained was:

$0.011 \times 0.253 \times 0.192 \times 0.010 \times 0.009 \times 0.008 \times 0.066 = 2.54 \times 10^{-11}$

Table 9.2 The antemortem dental traits of Tony Tanner and their prevalence in the database

DENTAL TRAIT	PREVALENCE
Prevalence of missing maxillary right central incisor, dentate, no bridge pontic, with or without 2-tooth acrylic upper partial denture	63 in 5521 (0.011)
Prevalence of synthetic filling on any surface of maxillary right lateral incisor	1398 in 5521 (0.253)
Prevalence of synthetic filling on any surface of maxillary right canine	1062 in 5521 (0.192)
Prevalence of caries on distal surface of maxillary right second premolar	57 in 5521 (0.010)
Prevalence of caries on buccal surface of mandibular right second molar	51 in 5521 (0.009)
Prevalence of caries of buccal surface of mandibular left second molar	44 in 5521 (0.008)
Prevalence of amalgam on occlusal surface of lower right first molar	363 in 5521 (0.066)

This probability is equivalent to one in 39 billion and it is, therefore, very unlikely that a person chosen at random would exhibit an identical dental configuration of these traits. It was concluded with statistical confidence that the remains and the missing person were one and the same.

9.4 Identification evidence presented at trial

Three men were charged with the execution-style murder of Tony Tanner. The case went to trial in the Tasmanian Supreme Court in March 2001, before the Chief Justice, William Cox.

The forensic dentist who had performed the original charting and comparisons gave evidence. She described the details of the case and the dental evidence discovered, and was cross-examined on many aspects of the case and on the principles of forensic odontology in general. The author, who had confirmed and checked the dental identification evidence with the examining forensic dentist, also gave evidence at the trial.

A forensic scientist informed the court that DNA coding of the remains was conducted and compared with a DNA profile of a near blood-relative of the deceased. There were technical limitations mitigating against a full

DNA profile and the loci examined did not include rare loci. The Government Analyst reported that one person in 246, chosen at random in the Tasmanian population, would have the same DNA profile.

In his evidence-in-chief, the author explained to the court how he had compiled a large database of dental traits of Tasmanians over a number of years. When the Crown Prosecutor attempted to lead testimony from the author regarding the characteristic dentition of the victim, the defence barristers objected, claiming that the witness was giving opinion evidence without the material (the database of dental traits), on which the opinion was based, being before the court.

The cross-examining barristers entered into legal debate with the judge on the admissibility of conclusions drawn from the database. After short discussion, the judge ordered that the jury retire so that counsel could present argument in *voire dire* (Appendix 2).

In the absence of the jury, the prosecutor asked the author to describe the history and structure of the database of dental traits. The author outlined how he had examined the database on the numbers of subjects who might have the identical dental traits of the victim. The result was that in the

entire set of records, there was not one individual with an identical set of traits.

The defence barristers were keen to limit the relevance of the database to a simple statement such as: "that by searching the database, it was established that the victim was not one of the individuals recorded." However, the database should be viewed in the broader context in that it is somewhat representative of the Tasmanian population, and therefore, it is permissible to draw the inference that if the dental configuration was unusual and highly characteristic, then it may be assumed that the perfect (fully corroborated) match obtained was unlikely to be due to chance alone. The chance of this being a random match would be one in 39 billion, thereby strengthening the proposition that the remains and Tony Tanner were one and the same. When questioned on this proposition by the judge, the author said,

> 'It does tell us by doing a survey, like when you do an opinion poll, it can tell you what the greater population is thinking ... that's how medical research is done. If you survey a thousand people on any medical trait, you will get some idea of what the greater population may have.'

The defence barristers were adamant that they did not want the author to draw inferences about the general population from the database.
When pressed on this point by the judge, the prosecutor summarised his desire to lead a simple proposition, that is,

> ' ...from those records, there is no-one else in Tasmania, ...a person with a combination of all these records doesn't turn up frequently.'

The defence barristers then put it to the author that the patient records in the database would not be representative of the general community. The author conceded this but commented that a truly representative sample in any population is elusive.

The quality of the data collected was then the subject of defence questioning. It was pointed out that the data was collected using a disciplined protocol and that the various dentists were tutored to interpret and tabulate the data in a set format. Every record was later checked by the author who then personally entered all the data into the database.

The prosecutor then wished to re-examine the witness. The author was asked about comparisons that he had made between the database and other international studies. It was stated by the author that the trait of a missing upper central incisor showed as 4.7% in Trondheim, Norway (Solheim, Schuller, 1999). He then pointed out that this same trait in the database had a prevalence of 3.2%, commenting that this was not a wide variance.

The defence then pushed their insistence that opinion evidence drawn from the database should not be presented unless the database itself was produced in court. They also claimed that the victim died in 1990 and the database commenced in 1996, and therefore no conclusions should be drawn from the information recorded in the database. Instead, the defence wished to allow it to be said only that the dental record of Tony Tanner was not on the database, thus showing that Tony Tanner was not a patient of my practice between 1996 and 2001; this being a meaningless statement as the man in question had died in 1990.

The prosecutor raised the analogy of fingerprint or DNA evidence, where an expert will say that the likelihood of random occurrence of certain traits is calculated from a database of records. He then told the judge he wished to lead to the jury the author's evidence set out in the author's proof of evidence:

> 'I have searched these databases for a match of all the characteristics that the skeleton shares with the dental records of Tony Tanner. I have been unable to find any individual to match these characteristics in the database.
>
> In my opinion, the dental records show that the skeleton is consistent with being Tony Tanner. Further it is very unlikely that a person chosen at random would exhibit an identical dental configuration of these traits.'

At the conclusion of lengthy argument from both sides and vigorous cross-examination of the author, Chief Justice Cox summed up the *voire dire*, in favour of the prosecution, thus:

> '... essentially the analogy between this and fingerprint evidence drawn by Mr Coates is a valid one'.

Chapter 10

Discussion

The new system developed to aid forensic identification, which is the subject of this thesis, has been successfully applied in establishing the identity of a murder victim and subsequently in defending this opinion in the Supreme Court of Tasmania in the trial Marlow & others for the murder of Tony Tanner.

Central to the application of this system to aid forensic identification, is the calculation of a probability value according to the principles of the product rule. In the valid application of this rule, it is a condition that the included items relate to independent events.

However, it is acknowledged that not all of the dental traits described here could be said to be independent of each other. For example, the presence of a synthetic filling on a maxillary canine indicates that this individual had a high caries risk. Such an individual would probably have experienced caries in the maxillary lateral incisor, and therefore be filled. Similarly, the mandibular molar of such a high-risk individual would most likely be restored. Hence, it could be argued that the probability of this set of events is the same as the probability of the filling in the upper maxillary canine alone. This being the case, then it could be argued that the probabilities relating to the maxillary lateral incisor and to the mandibular first molar should not enter the calculation of the probability product. Similarly, the probability of caries experience on the buccal surface of one mandibular second molar is likely to be the same as on the other, and likewise, only one, and not both of their separate probabilities should enter the calculation of the probability product. On the other hand, it may said that the missing central incisor is independent of these events, and that a more conservative estimate of the overall probability of the set of traits that correspond to that of Tony

Tanner is determined by restricting the probability terms in the calculation to the prevalence values of (1) the missing maxillary central incisor, (2) the synthetic filling on any surface of the maxillary right canine, (3) caries on the buccal surface of only one of the mandibular second molars, and (4) caries on the distal surface of the maxillary right second premolar. In this case, the number of terms to be multiplied together has been reduced from seven to four, to give:

Overall probability = $0.011 \times 0.192 \times 0.008 \times 0.010 = 1.69 \times 10^{-7}$

This probability is equivalent to about one in 17 million, somewhat more conservative than one in 39 billion but, never the less, is sufficiently

remote to make it highly likely that the remains in question are those of the missing person.

There is an increasing trend towards the use of expert witnesses in courts of law. The stringency of scientific credibility expected from such witnesses should ensure that forensic odontologists will strive to achieve higher levels of validity and accountability for the assertions that they make.

In the Marlow trial, the DNA evidence linking the identity of the remains with Tony Tanner was weak. Therefore, the dental identification evidence was crucial in strengthening the Crown assertion that the remains were in fact those of Tony Tanner. If the defence could establish that there was serious doubt that the remains were those of Tony Tanner, and the identity of the body could not be substantiated, then the prosecution case against the accused would probably collapse.

Before the trial, the author demonstrated to the prosecutor the details of statistical evidence, which could be presented in court to show that the combined dental traits of Tony Tanner were very characteristic.
Under cross-examination the author was not able to present detailed statistical evidence on trait prevalence from the database. The
prosecutor was allowed to ask the author about international studies on the prevalence of dental traits and the author was able to cite the Trondheim, Norway study (Solheim, Schuller, 1999). However, only rudimentary data on missing upper central incisors was illustrated.

A recent study in the United States analysed two large datasets of military and civilian individuals and found patterns of missing, filled and unrestored teeth to be highly distinctive and an excellent method of personal identification. Individual trait prevalences were not calculated.

Instead, the overall prevalence of a pattern of the whole dentition was calculated (Adams, 2003a, Adams, 2003b). In the Tasmanian trial, the author informed the court that the overall dental pattern of Tony Tanner was distinctive and unique; it did not conform with any other pattern among the database of 5521 individuals. Thus, the method employed to determine the identification of the remains of one deceased person could also be used for identification purposes in the case of a large scale incident involving may deaths.

The tactics of the defence barristers suggests that the introduction of statistical evidence from the database was a serious threat to the defence proposition that the remains were not those of Tony Tanner; the corollary being that the accused would have no case to answer.

The ruling in the *voire dire* in the Marlow trial allowed that reference to a dental trait database was permissible in relation to the construction of an expert opinion, and as such, set a precedent in Tasmanian case-law. The fact that only a fraction of the full capabilities of the database was invoked is of no great consequence; this evidence was accepted.

Although the Marlow case is at present the subject of an appeal to the High Court of Australia, the dental evidence was not challenged in the initial appeal in the Supreme Court of Tasmania, nor in the High Court.

The legal precedent set in the Marlow trial, that is, admission of dental trait evidence based on statistical analysis of dental trait material stored in a purpose-built database established by the author, may possibly offer encouragement for practising odontologists to further the concept of establishing and using reference databases of dental traits in population groups in other parts of Australia.

In relation to another Tasmanian case heard in the Court of Criminal Appeal, Justice Cox said,

> "Relative probabilities or improbabilities must frequently be an important factor in the evaluation of any expert opinion and, when any reliable statistical material is available which bears on this question, it must be part of the function and duty of the expert to take this into account (Jeffrey v The Queen, 1991)"

Traditionally, the prevalence of traits has been estimated by forensic dentists without any consistent basis for validity. The Battery Point sample is a collection of highly detailed records of a large number of dental patients. However, surveys of dental patients are not surveys of the population. Notwithstanding this, it may be reasonably assumed that a sample as large as the Battery Point sample, with high numbers in every

age group, might bear some resemblance to dental trait distribution in the wider Australian community. It must be noted also, that where a body is identified by dental trait matching, then *ipso facto* the deceased is, or once was, a dental patient.

Samples such as the Battery Point sample will have some relevance to the population as it exists at the time the sample is taken but will be subject to a decline in relevance as the population ages, dental treatment modalities evolve and the patterns of dental disease change. A project to continuously collect such data would be useful. Accordingly, future national oral health surveys should include some individual tooth and surface based statistics. As a minimum in such a survey, individual missing teeth should be recorded, as should filling types in individual teeth and tooth surfaces. The tooth status codes used in this study allow a quick and unambiguous recording of such data with minimal operator training.

10.1 Conclusion

This study has described the development of a system for recording detailed dental data obtained from population samples. A database

containing detailed dental data from a population sample has been established.

It has been demonstrated that, with reference to this database, it was possible to calculate the probability that the configuration of dental data, unique to a postmortem specimen, matched the configuration of a corresponding antemortem dental record, and hence determined the identity of the human from whom the specimen originated. Thus the hypothesis "The configuration of the dental tissues and dental restorative features are individually unique, therefore detailed dental records may be used as personal identification markers." is upheld.

APPENDIX 1

Where more complex data compilation is needed, the Scriptmaker function is used. Multiple Finds and analysing data within records requires the use of a Script. An example is where we wish to know how prevalent a trait, or number of traits, is in each of the standard 5-year age groups and tabulate the results for the whole sample. The appropriate Script is compiled in the Scriptmaker function and the Script can then be run to compute the results. Such data analysis is dependent on the ability of a computer to perform a large number of repeated searches and calculations for each of many records and this takes some time, even with a fast computer. Scripts were written for some of the data analysis in this study but the use of Scriptmaker is too complex for inclusion in this outline of FileMaker Pro 4.0 functions.

APPENDIX 2

Voir dire (*voire dire*)

(Norman French: to speak the truth)

An inquiry conducted by the judge in the absence of the jury into the admissibility of an item of evidence. It is sometimes called a trial within a trial. A special oath is taken by witnesses called to testify on the *voir dire.*

(Dictionary of Law, Oxford University Press, Market House Books Ltd, 1997)

APPENDIX 3

Disaster Victim Identification (DVI) is the term given to procedures used to positively identify deceased victims of a multiple casualty event. It is recognised that occasions may arise where there may be only one deceased person but due to the condition of the body DVI procedures are followed where appropriate. One of the greatest problems arising in any multiple casualty incident is the identification of victims to the satisfaction of the coroner. This problem is aggravated when the condition of victims is such that visual identification is unreliable.

Positive identification is not only a legal requirement but is something that is socially expected of those charged with this responsibility despite religion or race. Identification of victims and their position prior to the incident will often assist investigators in establishing a cause.

In Tasmania, legal possession and control of the human remains is vested in the coroner. For the purposes of DVI investigation police have this responsibility although in reality they play only one part in an exercise that involves numerous agencies of various disciplines. A cooperative and

coordinated approach by all parties is essential for any chance of success in this onerous and stressful task.

(DVI Procedure Manual, Tasmanian Coronial Services Plan, December 1999.)

APPENDIX 4

Table A1. Tooth 11. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	8	1
AO	2	0
AD	14	5
AB	1	1
AL	62	19
AMO	1	1
ADO	0	0
AOB	0	0
AOL	0	0
AMOD	0	0
AMODB	0	0
AMODL	0	0
AMODBL	0	0
SM	884	103
SO	519	29
SD	991	228
SB	581	104
SL	670	9
SMO	342	57
SDO	97	26
SOB	232	23
SOL	256	6
SMOD	159	49
SMODB	66	11
SMODL	37	33
SMODBL	51	46
G	85	
PBM	200	
X	425	
X,P	31	

Table A2. Tooth 12. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	3	0
AO	6	5
AD	26	0
AB	3	0
AL	328	158
AMO	0	0
ADO	1	1
AOB	0	0
AOL	0	0
AMOD	0	0
AMODB	0	0
AMODL	0	0
AMODBL	0	0
SM	944	179
SO	285	12
SD	671	79
SB	465	80
SL	580	37
SMO	226	35
SDO	35	9
SOB	115	6
SOL	154	2
SMOD	102	18
SMODB	51	12
SMODL	25	19
SMODBL	38	31
G	69	
PBM	142	
X	588	
X,P	45	

Table A3. Tooth 13. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	32	3
AO	43	4
AD	408	79
AB	9	3
AL	260	10
AMO	6	1
ADO	25	8
AOB	0	0
AOL	19	3
AMOD	3	2
AMODB	0	0
AMODL	0	0
AMODBL	0	0
SM	565	82
SO	186	9
SD	334	46
SB	528	191
SL	364	11
SMO	136	20
SDO	26	8
SOB	88	3
SOL	90	4
SMOD	57	11
SMODB	34	6
SMODL	25	19
SMODBL	25	20
G	40	
PBM	93	
X	565	
X,P	10	

Table A4. Tooth 14. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	457	1
AO	1244	145
AD	1030	6
AB	53	0
AL	53	1
AMO	454	41
ADO	621	502
AOB	47	1
AOL	43	1
AMOD	395	236
AMODB	29	16
AMODL	25	18
AMODBL	8	5
SM	269	2
SO	433	38
SD	319	2
SB	441	93
SL	71	0
SMO	254	23
SDO	112	76
SOB	161	1
SOL	57	1
SMOD	201	71
SMODB	104	74
SMODL	16	13
SMODBL	20	13
G	60	
PBM	105	
X	1305	
X,P	35	

Table A5. Tooth 15. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	866	1
AO	1432	129
AD	1112	7
AB	72	2
AL	93	1
AMO	858	135
ADO	425	368
AOB	66	1
AOL	83	3
AMOD	669	494
AMODB	46	29
AMODL	52	32
AMODBL	11	8
SM	249	4
SO	415	34
SD	283	3
SB	268	35
SL	60	1
SMO	236	33
SDO	89	66
SOB	122	6
SOL	49	1
SMOD	181	90
SMODB	63	44
SMODL	19	13
SMODBL	11	10
G	58	
PBM	81	
X	1211	
X,P	41	

Table A6. Tooth 16. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	1435	1
AO	2446	451
AD	1028	3
AB	305	0
AL	1095	13
AMO	1424	275
ADO	216	94
AOB	292	12
AOL	1046	243
AMOD	791	260
AMODB	168	43
AMODL	297	242
AMODBL	117	97
SM	267	1
SO	543	96
SD	210	1
SB	260	8
SL	253	13
SMO	243	34
SDO	61	12
SOB	145	7
SOL	196	36
SMOD	135	30
SMODB	59	16
SMODL	37	29
SMODBL	37	28
G	67	
PBM	73	
X	1053	
X,P	16	

Table A7. Tooth 17. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a one or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	981	2
AO	2308	871
AD	526	2
AB	409	2
AL	426	4
AMO	976	375
ADO	157	87
AOB	397	57
AOL	404	143
AMOD	354	126
AMODB	156	93
AMODL	48	41
AMODBL	50	45
SM	162	2
SO	392	135
SD	109	1
SB	119	7
SL	86	2
SMO	148	45
SDO	48	15
SOB	71	5
SOL	66	16
SMOD	54	16
SMODB	23	10
SMODL	9	7
SMODBL	9	6
G	52	
PBM	32	
X	1052	
X,P	2	

Table A8. Tooth 18. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	188	1
AO	675	371
AD	68	0
AB	102	6
AL	46	4
AMO	186	111
ADO	38	19
AOB	87	28
AOL	41	16
AMOD	28	11
AMODB	15	11
AMODL	1	1
AMODBL	2	2
SM	35	1
SO	108	53
SD	17	1
SB	38	1
SL	11	2
SMO	28	9
SDO	9	3
SOB	21	5
SOL	6	2
SMOD	4	0
SMODB	3	3
SMODL	1	1
SMODBL	0	0
G	10	
PBM	2	
X	3669	
X,P	0	

Table A9. Tooth 21. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	8	2
AO	2	1
AD	14	4
AB	2	0
AL	77	22
AMO	1	0
ADO	0	0
AOB	0	0
AOL	1	0
AMOD	0	0
AMODB	0	0
AMODL	0	0
AMODBL	0	0
SM	879	120
SO	490	21
SD	955	194
SB	561	115
SL	661	15
SMO	324	58
SDO	105	27
SOB	212	21
SOL	246	6
SMOD	153	44
SMODB	73	15
SMODL	32	27
SMODBL	57	47
G	80	
PBM	187	
X	419	
X,P	30	

Table A10. Tooth 22. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	12	0
AO	6	2
AD	32	3
AB	2	0
AL	321	156
AMO	1	0
ADO	1	0
AOB	0	0
AOL	2	0
AMOD	1	0
AMODB	0	0
AMODL	0	0
AMODBL	0	0
SM	980	184
SO	286	5
SD	662	87
SB	494	96
SL	615	35
SMO	228	27
SDO	35	11
SOB	126	6
SOL	158	4
SMOD	110	18
SMODB	57	17
SMODL	31	23
SMODBL	38	30
G	58	
PBM	136	
X	569	
X,P	44	

Table A11. Tooth 23. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	21	6
AO	53	4
AD	393	60
AB	22	3
AL	284	19
AMO	5	1
ADO	34	8
AOB	3	0
AOL	25	5
AMOD	2	0
AMODB	1	0
AMODL	1	1
AMODBL	0	0
SM	510	97
SO	148	10
SD	323	48
SB	548	251
SL	377	11
SMO	94	16
SDO	28	7
SOB	60	5
SOL	72	3
SMOD	29	6
SMODB	13	3
SMODL	7	5
SMODBL	10	7
G	41	
PBM	86	
X	576	
X,P	8	

Table A12. Tooth 24. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	464	0
AO	1251	148
AD	1011	6
AB	59	3
AL	69	2
AMO	461	41
ADO	604	470
AOB	49	2
AOL	56	1
AMOD	391	241
AMODB	23	17
AMODL	36	16
AMODBL	2	2
SM	272	2
SO	441	35
SD	333	1
SB	423	71
SL	80	2
SMO	254	17
SDO	108	63
SOB	154	1
SOL	68	0
SMOD	216	90
SMODB	90	60
SMODL	28	26
SMODBL	21	18
G	42	
PBM	116	
X	1290	
X,P	24	

Table A13. Tooth 25. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	891	1
AO	1493	150
AD	1160	4
AB	74	2
AL	112	0
AMO	889	128
ADO	430	377
AOB	70	2
AOL	104	3
AMOD	719	521
AMODB	47	26
AMODL	67	47
AMODBL	10	8
SM	263	4
SO	409	37
SD	275	2
SB	245	22
SL	64	2
SMO	250	30
SDO	72	52
SOB	123	1
SOL	54	0
SMOD	193	90
SMODB	69	49
SMODL	25	23
SMODBL	9	6
G	35	
PBM	82	
X	1184	
X,P	27	

Table A14. Tooth 26. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	1439	5
AO	2468	432
AD	1135	2
AB	383	1
AL	1107	20
AMO	1425	237
ADO	229	102
AOB	373	22
AOL	1055	225
AMOD	892	279
AMODB	232	78
AMODL	332	272
AMODBL	146	122
SM	289	1
SO	628	138
SD	237	0
SB	204	4
SL	233	7
SMO	280	38
SDO	75	16
SOB	129	4
SOL	196	31
SMOD	154	46
SMODB	55	19
SMODL	40	35
SMODBL	29	23
G	74	
PBM	76	
X	1013	
X,P	11	

Table A15. Tooth 27. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	1052	2
AO	2281	783
AD	571	3
AB	392	4
AL	455	10
AMO	1045	401
ADO	165	80
AOB	375	58
AOL	438	130
AMOD	398	154
AMODB	149	80
AMODL	68	58
AMODBL	62	50
SM	174	1
SO	442	158
SD	111	0
SB	126	5
SL	95	8
SMO	167	49
SDO	38	11
SOB	72	6
SOL	74	18
SMOD	64	20
SMODB	28	17
SMODL	10	9
SMODBL	9	7
G	50	
PBM	12	
X	1108	
X,P	0	

Table A16. Tooth 28. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	227	1
AO	673	358
AD	69	0
AB	120	9
AL	42	0
AMO	226	123
ADO	25	15
AOB	106	33
AOL	41	9
AMOD	43	15
AMODB	21	15
AMODL	5	3
AMODBL	5	5
SM	39	3
SO	104	37
SD	14	0
SB	43	5
SL	11	0
SMO	34	19
SDO	8	1
SOB	27	13
SOL	9	3
SMOD	6	3
SMODB	3	2
SMODL	0	0
SMODBL	1	1
G	6	
PBM	2	
X	3709	
X,P	0	

Table A17. Tooth 31. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	10	2
AO	6	2
AD	7	1
AB	5	1
AL	15	0
AMO	3	0
ADO	0	0
AOB	1	1
AOL	3	0
AMOD	0	0
AMODB	0	0
AMODL	0	0
AMODBL	0	0
SM	198	52
SO	198	39
SD	218	55
SB	116	35
SL	83	2
SMO	85	19
SDO	48	30
SOB	47	10
SOL	49	9
SMOD	51	28
SMODB	15	1
SMODL	7	7
SMODBL	13	11
G	18	
PBM	17	
X	98	
X,P	9	

Table A18. Tooth 32. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	11	4
AO	8	1
AD	27	8
AB	15	6
AL	19	2
AMO	4	0
ADO	1	0
AOB	0	0
AOL	5	0
AMOD	0	0
AMODB	0	0
AMODL	0	0
AMODBL	0	0
SM	217	78
SO	140	31
SD	175	46
SB	130	44
SL	75	0
SMO	63	19
SDO	28	17
SOB	32	9
SOL	35	4
SMOD	27	12
SMODB	10	2
SMODL	4	2
SMODBL	8	7
G	17	
PBM	13	
X	106	
X,P	3	

Table A19. Tooth 33. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	23	4
AO	26	5
AD	130	41
AB	69	28
AL	65	0
AMO	1	0
ADO	12	3
AOB	5	1
AOL	7	1
AMOD	0	0
AMODB	0	0
AMODL	0	0
AMODBL	0	0
SM	145	49
SO	95	24
SD	118	21
SB	271	147
SL	57	0
SMO	34	6
SDO	16	5
SOB	35	10
SOL	17	1
SMOD	19	7
SMODB	8	4
SMODL	3	2
SMODBL	3	3
G	13	
PBM	16	
X	221	
X,P	0	

Table A20. Tooth 34. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	210	4
AO	910	142
AD	675	9
AB	202	68
AL	51	5
AMO	201	37
ADO	510	344
AOB	103	16
AOL	40	0
AMOD	141	71
AMODB	24	15
AMODL	9	5
AMODBL	6	5
SM	74	1
SO	204	26
SD	144	3
SB	433	184
SL	36	0
SMO	63	5
SDO	92	54
SOB	74	3
SOL	32	2
SMOD	41	7
SMODB	22	11
SMODL	10	7
SMODBL	7	4
G	25	
PBM	32	
X	740	
X,P	4	

Table A21. Tooth 35. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	546	3
AO	1430	215
AD	1073	6
AB	191	17
AL	105	1
AMO	537	66
ADO	635	506
AOB	156	18
AOL	97	3
AMOD	422	266
AMODB	63	42
AMODL	52	42
AMODBL	13	10
SM	117	3
SO	306	43
SD	215	0
SB	264	59
SL	61	0
SMO	110	7
SDO	121	73
SOB	83	8
SOL	50	1
SMOD	85	33
SMODB	35	20
SMODL	13	9
SMODBL	14	11
G	39	
PBM	37	
X	1064	
X,P	16	

Table A22. Tooth 36. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	999	0
AO	2005	380
AD	1053	0
AB	1022	48
AL	489	1
AMO	998	113
ADO	332	127
AOB	885	194
AOL	479	11
AMOD	718	170
AMODB	391	184
AMODL	121	89
AMODBL	187	157
SM	174	1
SO	513	130
SD	213	1
SB	286	19
SL	172	0
SMO	166	10
SDO	91	24
SOB	158	29
SOL	157	9
SMOD	112	20
SMODB	54	13
SMODL	29	18
SMODBL	38	26
G	124	
PBM	74	
X	1402	
X,P	16	

Table A23. Tooth 37. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	942	3
AO	2216	862
AD	461	3
AB	699	24
AL	341	0
AMO	936	322
ADO	113	40
AOB	625	177
AOL	335	23
AMOD	337	79
AMODB	181	83
AMODL	61	46
AMODBL	88	74
SM	153	2
SO	451	173
SD	105	1
SB	197	17
SL	103	1
SMO	146	40
SDO	51	15
SOB	93	22
SOL	93	7
SMOD	49	10
SMODB	22	9
SMODL	15	5
SMODBL	12	10
G	75	
PBM	32	
X	1274	
X,P	3	

Table A24. Tooth 38. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	197	1
AO	880	460
AD	99	1
AB	271	24
AL	78	0
AMO	196	81
ADO	53	20
AOB	234	118
AOL	75	7
AMOD	42	6
AMODB	27	17
AMODL	7	6
AMODBL	8	8
SM	33	0
SO	99	72
SD	17	0
SB	35	3
SL	2	0
SMO	32	11
SDO	17	5
SOB	32	10
SOL	18	0
SMOD	5	3
SMODB	0	0
SMODL	0	0
SMODBL	0	0
G	18	
PBM	4	
X	3519	
X,P	0	

Table A25. Tooth 41. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	9	2
AO	2	1
AD	16	9
AB	3	2
AL	8	0
AMO	1	0
ADO	0	0
AOB	0	0
AOL	1	0
AMOD	1	0
AMODB	0	0
AMODL	1	1
AMODBL	0	0
SM	165	34
SO	76	42
SD	138	57
SB	37	33
SL	12	0
SMO	71	19
SDO	56	38
SOB	43	12
SOL	48	18
SMOD	36	22
SMODB	11	4
SMODL	2	0
SMODBL	7	6
G	27	
PBM	13	
X	99	
X,P	8	

Table A26. Tooth 42. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	11	4
AO	5	1
AD	13	6
AB	8	4
AL	9	2
AMO	3	1
ADO	0	0
AOB	0	0
AOL	2	0
AMOD	0	0
AMODB	0	0
AMODL	0	0
AMODBL	0	0
SM	211	71
SO	140	37
SD	178	54
SB	142	53
SL	60	3
SMO	67	27
SDO	22	15
SOB	31	8
SOL	25	3
SMOD	28	12
SMODB	13	5
SMODL	2	2
SMODBL	7	6
G	14	
PBM	11	
X	120	
X,P	2	

Table A27. Tooth 43. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	12	2
AO	27	6
AD	135	25
AB	87	30
AL	75	3
AMO	2	0
ADO	16	9
AOB	4	0
AOL	7	1
AMOD	0	0
AMODB	0	0
AMODL	0	0
AMODBL	0	0
SM	143	35
SO	94	25
SD	124	24
SB	255	140
SL	70	2
SMO	28	4
SDO	24	8
SOB	31	7
SOL	28	2
SMOD	14	2
SMODB	8	2
SMODL	2	2
SMODBL	6	4
G	11	
PBM	6	
X	245	
X,P	1	

Table A28. Tooth 44. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	225	4
AO	914	128
AD	686	8
AB	220	62
AL	35	2
AMO	209	44
ADO	528	385
AOB	120	8
AOL	29	2
AMOD	135	67
AMODB	33	22
AMODL	4	2
AMODBL	5	3
SM	82	1
SO	228	18
SD	178	5
SB	386	168
SL	37	2
SMO	69	5
SDO	110	44
SOB	73	9
SOL	30	1
SMOD	47	15
SMODB	18	11
SMODL	6	6
SMODBL	6	5
G	23	
PBM	32	
X	749	
X,P	4	

Table A29. Tooth 45. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	573	6
AO	1431	198
AD	1072	4
AB	183	14
AL	86	3
AMO	566	86
ADO	620	487
AOB	151	16
AOL	78	1
AMOD	435	269
AMODB	74	49
AMODL	40	23
AMODBL	16	13
SM	156	0
SO	325	31
SD	246	3
SB	281	54
SL	66	1
SMO	147	13
SDO	116	72
SOB	93	4
SOL	59	1
SMOD	116	40
SMODB	51	31
SMODL	20	14
SMODBL	13	9
G	60	
PBM	52	
X	1065	
X,P	11	

Table A30. Tooth 46. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	1110	1
AO	2030	363
AD	1052	2
AB	1035	51
AL	424	0
AMO	1102	139
ADO	278	111
AOB	890	196
AOL	419	11
AMOD	766	199
AMODB	405	181
AMODL	106	77
AMODBL	181	146
SM	209	1
SO	535	100
SD	227	0
SB	332	30
SL	190	0
SMO	204	12
SDO	86	20
SOB	176	40
SOL	172	3
SMOD	132	24
SMODB	49	17
SMODL	50	30
SMODBL	29	25
G	106	
PBM	69	
X	1358	
X,P	18	

Table A31. Tooth 47. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	1001	0
AO	2235	832
AD	481	6
AB	704	28
AL	324	1
AMO	995	354
ADO	125	42
AOB	635	179
AOL	317	21
AMOD	343	88
AMODB	182	81
AMODL	55	47
AMODBL	88	81
SM	157	0
SO	422	160
SD	90	2
SB	191	21
SL	89	0
SMO	152	43
SDO	33	8
SOB	91	21
SOL	78	3
SMOD	50	16
SMODB	18	7
SMODL	13	11
SMODBL	9	8
G	74	
PBM	39	
X	1206	
X,P	4	

Table A32. Tooth 48. Frequency of restoration type or condition (5521 individuals).

Restoration type	Appearing as: (1) sole restoration or (2) part of a two or more surfaces restoration type or (3) in conjunction with other separate restoration types on this (these) surface(s)	Appearing as sole restoration
AM	212	0
AO	858	471
AD	77	0
AB	235	20
AL	63	0
AMO	211	83
ADO	29	14
AOB	201	92
AOL	59	6
AMOD	46	12
AMODB	0	0
AMODL	0	0
AMODBL	0	0
SM	38	1
SO	153	74
SD	24	1
SB	86	10
SL	21	1
SMO	36	11
SDO	11	5
SOB	34	11
SOL	14	2
SMOD	10	2
SMODB	4	3
SMODL	2	2
SMODBL	1	0
G	19	
PBM	3	
X	3484	
X,P	0	

Table A33. Frequency of dentures (5521 individuals).

Denture type	
Full maxillary denture Full mandibular denture	182 6
Maxillary acrylic-based partial	130
Maxillary chrome-based partial	205
Mandibular acrylic-based partial	31
Mandubular chrome-based partial	107

Table A34. Frequency of retained deciduous tooth, aged greater than 16 years (5521 individuals).

Tooth	
Upper right canine	10
Upper left canine	11
Lower right canine	0
Lower left canine	1
Upper right second premolar	4
Upper left second premolar	8
Lower right second premolar	23
Lower left second premolar	22

Table A35. Gender (5521 individuals).

Male	2407
Female	3114

Table A35. Frequency of patterns (5521 individuals).

Trait	
All teeth present and unfilled	13
All teeth present and unfilled (third molars not considered)	154
All teeth present and unfilled (third molars extracted or unerupted)	109
Third molars extracted or unerupted	2451

APPENDIX 5

HUMAN ETHICS COMMITTEE approval

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