EVALUATION OF TWO DENTAL IDENTIFICATION COMPUTER SYSTEMS: DAVID and WinID3

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ABSTRACT

Human identification, by comparing dental characteristics, is considered to be one of the most reliable, accurate and rapid methods of resolving the identity of visually un-identifiable deceased persons. In recent decades computer programs have evolved to aid odontologists by suggesting records that have similar dental features. The aim of the present study was to compare two of those programs; Disaster And Victim IDentification (DAVID) and WinID3 in terms of effectiveness, accuracy and speed of data entry and to further compare them with the efficiency of the classical method of manually matching postmortem and antemortem dental records. An open disaster was simulated whereby 52 fragmented remains made of acrylic replicas and 77 provisional victims were represented on Interpol F2 postmortem and antemortem forms. The results assessed were the first seven possible matches made by each program. Manual matching of dental characteristics performed better than both programs ($P<0.001$) yielding 29 identifications. Eleven and six positive matches were the result of the DAVID and the WinID3 programs respectively ($P=0.185$). Data entry was quicker for WinID3. It was concluded that both programs are still not as accurate as the time-consuming manual matching method. The difference in performance between the DAVID and the WinID3 programs was attributed to the inclusion of more comparable dental characteristics, the inclusion of the type of dentition (deciduous or permanent) and the weighting of those characteristics by the DAVID program.

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Key words: disaster, identification, forensic odontology, computer, DAVID, WinID

INTRODUCTION

Disaster is defined as a sudden occurrence that exceeds the resources available in a community to deal with, including a large number of fatalities as a result.[1] The importance of victim identification is valued worldwide. It will not only resolve serious legal and social predicaments, but also it provides a resolution to grieving families who need closure of their sadness.[2] For those reasons, disaster victim identification (DVI) was globally formalized by Interpol in 1984 with the production of the first DVI manual.[3]

Identification of the deceased is usually performed visually by the next of kin, but this approach is neither reliable nor desirable when there are multiple victims, the body has undergone postmortem decomposition or if death was a violent one (e.g. incineration, motor and aviation accidents). In such circumstances the identity must be achieved by alternative means. Medical and dental characteristics, fingerprints, and DNA comparisons are regarded internationally as scientific methods of identification.[2,3] The uniqueness of each dentition was demonstrated without the use of dental radiographs.[4] Teeth have shown a diversity that was comparable to that of mitochondrial DNA[5] even when the incidence of dental decay and restorations was declining.[6] Uniqueness of teeth together with their remarkable ability to sustain harsh circumstances make dental characteristics a reliable, and often the only identification method available.

When forensic experts are dealing with many victims, as was the case in the recent Indian Ocean tsunami when, for example, more than 5000 victims needed to be identified in Thailand alone,[7] the process becomes complex due to the large volume of postmortem and antemortem data that need to be collected and then compared. A computer program that can be employed to store, sort and match antemortem and postmortem records in a speedy and accurate manner seems highly desirable.

Forensic odontologists have attempted to simplify the diversity of dental characteristics to facilitate comparison particularly following a mass disaster.[8-11] The first reported computer-aided dental identification system: Dental Identification Package (DIP) was described by Kogon *et al.* in 1974.[12] In 1977, Siegel *et al.* proposed quantifying dental characteristics by giving weight to each in a changeable algorithm.[13] This was followed by the introduction of Computer Assisted Postmortem Identification (CAPMI) program by Lorton *et al.*[14] to be followed by publication of several programs with different matching philosophies.[15-18] Those programs have been assisting forensic odontologists in identifying victims of mass disasters by producing possible matches.

The purpose of the present study was to compare two dental identification systems; the WinID3, which is the latest version of WinID and the DAVID* programs with regards to accuracy of the matching process and time efficiency, and to compare their performance with the classical method of manually matching the same set of simulated remains.

MATERIALS AND METHODS

An open mass disaster situation with 52 badly mutilated victims was simulated. The victims were represented by 52 acrylic replicas of mandibles (n=26), maxillae (n=6), skulls (n=17) and jaw fragments (n=3) (Fig. 1). This was part of a national training set which has been used by the Australian Federal Police for multidisciplinary DVI training. The dental features were variable and included sound and missing teeth, restorations with various dental materials and root canal treatments created by using extracted natural human teeth which were embedded in the acrylic replicas, together with fixed and removable prostheses. All dental characteristics were charted onto Interpol F2 forms.

* During the writing of this manuscript, updated versions of the DAVID and the WinID3 programs were being produced. The algorithms and dental characteristics of both programs remained unchanged to the versions on which this study was performed.

Fig.1: *the DVI training set representing acrylic replicas of the fragmented remains. (Courtesy Mr. Ronn Taylor, forensic sculpture; and Mr. Chris Owen, photographer. School of Dental Science, The University of Melbourne)*

The antemortem data of imaginary victims was transcribed onto 52 Interpol F2 forms and was part of the DVI training kit. Some of those forms had the sentence "no records available" while others contained a variety of dental information ranging from simple dental data to complex dental treatment including multiple restorations and crown and bridge work. In order to simulate an open disaster, another 25 antemortem records, which were transcribed anonymously from actual identification cases performed by the forensic odontology team at the Victorian Institute of Forensic Medicine in Melbourne, Australia, were added to the antemortem collection.

All records were matched manually aiming at reaching maximum concordance. This process began by sorting antemortem and postmortem records into females, males and unknown gender. Then each gender group was divided into age groups by the date of birth (in case of antemortem records) and by chronological dental eruption pattern (in case of postmortem records); those age groups were: 0-5 years, represented by deciduous dentition; 6-12 years, represented by mixed dentition; and 13 and above years represented by permanent dentition. The records were further divided into those with fixed and removable prostheses, restorations, and no dental treatment groups. The outcome of the manual matching was classified as either "positive", "possible", or "inconsistent". Positive identification was considered to be when there was sufficient concordance between antemortem and postmortem dental records to establish the identity beyond any reasonable doubt. Possible identification was considered to be when the dental information in an antemortem record was not identical with that in a postmortem record but could have evolved into it during life. Insufficient antemortem data was also designated as possible. Inconsistent identification was considered to be when there was obvious unexplainable inconsistency between antemortem and postmortem dental characteristics. In order to obtain the best outcome for comparison, only records which were considered positive were used in assessing computer matching results.

A period of familiarization with both programs was undertaken, following which the postmortem and antemortem dental records were entered separately and alternately (all antemortem records followed by all postmortem records into the DAVID program, then all antemortem records followed by all postmortem records into the WinID3 program). Data entry was performed by the same operator (SA) so as to avoid inter-examiner differences. The time for the data entry was measured.

The matching command for each program was activated; the "Most Dental Hits" option in WinID3 and the "Match" command in DAVID. The DAVID's algorithm settings that applied in Australia were used (Table 1). Other identification tools such as a targeted search for a specific dental feature and other matching lists of WinID3 were not used. Each manually identified postmortem case was matched to all antemortem cases in the database. The

Table 1: *Algorithm of the "DAVID Web" program*

PM/AM	Bridge	Crown	Decayed	Dentures	Missing	No data	Sound	Restorations	Unerupted
Bridge	100	10	10	10	10	0	10	10	10
Crown	10	100	10	-1000	-1000	0	10	10	10
Decayed	10	10	10	-1000	-1000	0	100	10	10
Dentures	10	10	10	100	100	0	10	10	10
Missing	100	10	10	100	100	0	10	10	10
No data	10	10	10	10	10	10	10	10	10
Sound	-1000	-1000	-1000	-1000	-1000	0	100	-100	100
Restorations	0	0	0	-1000	-1000	0	10	100	10
Unerupted	-1000	-1000	-1000	-1000	10	0	-1000	-1000	100

	Match	Mis-match
Deciduous	100	-1000
Filling Surface	100	-1000
Root filled/Implant	100	-1000

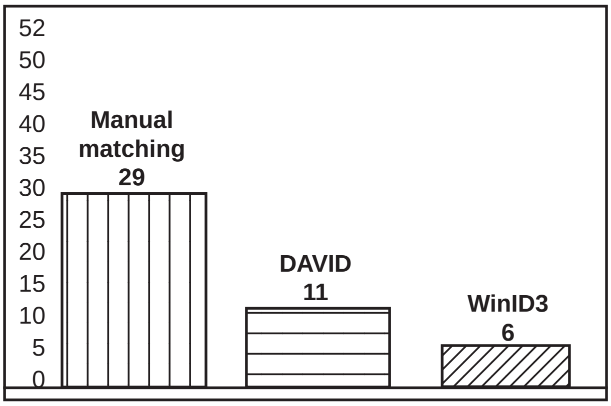

***Fig.2**: Results of the matching outcome of the 52 PM records using the three methods: manual, DAVID and WinID3 programs*

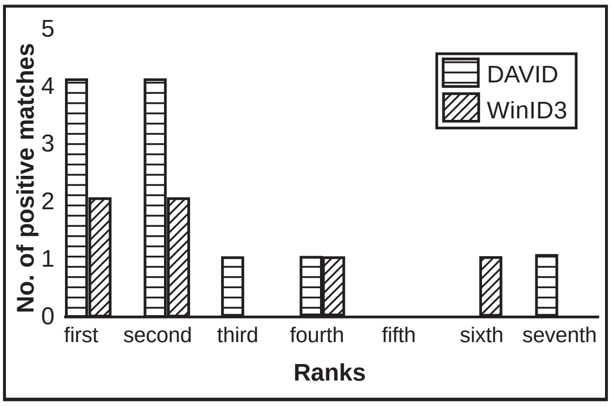

***Fig. 3**: Results of the first seven ranks performed by the DAVID and WinID3 programs whereby the first rank is the most likely match*

outcome of both programs was presented in a list starting from the most likely match (greatest score) to the least likely match (least score). The first seven matches of both programs were collected and the results were analyzed using the Chi-Square test with $p<0.05$ being taken as significant.

RESULTS

Time spent for data entry of the 129 dental records was approximately 7 hours and 30 minutes for DAVID and approximately 6 hours for WinID3 program. Time spent for manual matching was approximately 22 hours.

The number of postmortem records that were identified as "positive" using the manual method was 29/52 (Fig. 2). Of the 29 records, the DAVID program successfully identified 11 records (Fig. 2), four of those records were identified as the most likely match, four records were identified as the second most likely match and three records were in the remaining five matches of the list of seven (Fig. 3).

The WinID3 program was successful in identifying 6 postmortem records out of the 29 manually identified (Fig. 2). Two records were identified as the most likely match, two records were identified as the second most likely match and two records were in the remaining five matches of the list of seven (Fig. 3).

The manual method was significantly better than the DAVID and WinID3 programs ($p<0.001$), however, there was no significant difference between both programs ($p=0.185$).

Three records had sufficient characteristics that satisfied the matching criteria of both programs.

DISCUSSION

In the present study, the matching performance of the DAVID and the WinID3 programs was not significantly different. Data entry was quicker for WinID3. WinID3 is designed with an algorithm that is based on "hits and misses". A hit is equal to one point and a miss is equal to zero. The aggregate score is presented to the operator in five different data sets; most dental hits, least dental mis-matches, most identifier matches, most restoration hits and fuzzy dental logic. There are four dental characteristics designated "primary codes" used in the matching algorithm in addition to five restored surfaces of each tooth (one hit per matched restoration). The primary codes are: missing, missing crown, missing post-mortem, un-erupted and virgin.[19] The primary code "no info", although listed as a primary code, does not contribhute to the overall score". A crown is automatically changed into five restored surfaces and is given one hit. In addition to this, there are 12 secondary codes which are not part of the algorithm and do not contribute to the matching score. They do, however, provide additional information for the operator to assess possible matches suggested by WinID3 system.[16,19]

The algorithm of the DAVID program gives quantitative values to each dental characteristic depending on its significance and rarity in the community; the more unique the characteristic the greater its weight. Those weights range from "100" to "minus (-)1000" where 100 is the weight of matching a unique characteristic, such as matching a crown to a crown and -1000 is a penalty aimed at the exclusion of that match when there is an obvious inconsistency. Values in between indicate possible matches. For example, a match between an antemortem sound tooth and a postmortem extracted tooth results in a score of 10 points, whereas the opposite results in a score of -1000 and hence DAVID predicts, to some extent, the possible change of one characteristic into another. These algorithm values are changeable by a "superuser" according to their perception of dental features in a respective community. In the present study the settings that applied in Australia were used.[15,25]

In DAVID there are 11 dental characteristics, all of which are primary. Those characteristics are: sound, damaged, bridge, crown, denture, missing, socket, un-erupted, root, single-surface filling and multi-surface filling. Contrary to WinID3, each tooth receives one of those characteristics *plus* the type of dentition (deciduous or permanent) and the filled surfaces of each tooth which are weighted separately.

Quantifying dental data has been proposed previously.[13,20-22] In the present study, it was observed that the DAVID program showed more ability to match fragmented remains by comparison with WinID3. This can be attributed to expanding matchable characteristics (including deciduous teeth) and to quantifying them. The WinID2 program (earlier version of WinID3), performed best when "most restoration hits" list was used.[23] In the present study the "most dental hits" list was used to assess the results. This option of the WinID3 program was considered most applicable to our study sample. Although DAVID's Graphic-User Interface data entry was intended to be a simple way of entering dental records, WinID3 program's data entry was quicker because it allowed characteristics to be entered by the keyboard as codes or by a mouse from a menu, contrary to DAVID where data entry was restricted to the use of a mouse. For example, a mesio-occlusal filling on a deciduous tooth can be entered as codes (MO B) in the WinID3 program, while in the DAVID program, the operator will need to click on the icon of the filling, then on the mesial and occlusal surfaces, then on the tooth number to change it to a deciduous

Table 2*: Comparison of some of the main features of DAVID and WinID3 programs.*[25]

Feature	DAVID	WinID3
Matching algorithm	Qualitative and quantitative	Quantitative only
Primary dental characteristics	11 codes (+ 5 surfaces)	5 codes (+ 5 surfaces)
Secondary dental characteristics (not matchable)	None	12 codes
Deciduous teeth	Scored	Not scored
Password required	Yes	No
Auditing	Yes	No
Numerical systems	Only European system: kg, cm	European and North American systems: kg, cm and lb, inch.
Languages	English	English, French, German, Italian, Portuguese and Spanish
Accessing records	Slow: accesses one record at a time.	Quick: accesses multiple records.
Dentist details	Compulsory	Not compulsory
Image attachment	Not able	Able
Ability to work with more than one database	Yes, up to 7 databases	No
Ability to provide statistics	Not able	Able
Printing	Able to print records similar to Interpol F2 forms, in addition to disaster and dentist details.	Able to print records with physical and dental details.

tooth. The measuring of time of data entry was a crude attempt to assess the friendliness of both programs.

The cases which the DAVID program successfully identified in the first seven attempts and which WinID3 failed to identify were those with deciduous dentition, prosthodontic work and those which were severely fragmented. This highlights the value of including the type of dentition as a matchable dental characteristic. It also highlights the importance of having an algorithm which weights characteristics so that a fixed prosthesis would contribute significantly to the score producing a more probable match. The cases in which WinID3 was successful and in which DAVID failed, represented records rich in dental data which allowed accumulating a large number of hits. As was expected the three postmortem records that were identified by both programs reflected comprehensive antemortem dental records and less fragmented postmortem remains. The programs were not able to match fragmented remains with root canal treatments because neither program used in the present study was equipped in their algorithm to match this dental characteristic.

The manual matching, although time consuming, led to significantly better outcome than both programs ($p<0.001$). It was concluded that the diversity of dental characteristics exceeded the capabilities of the two software programs in their present format. Contrary to identification programs that are designed to match other antemortem and postmortem data (such as DNA profiles), dental identification programs have the additional task of accommodating changes to the dentition produced by dentists (sometimes in multiple records), hence it is not an easy task to write a program that can precisely match a changing dentition. This study should not be interpreted as failure of computer-aided dental identification rather it should stimulate further improvement of this vital and promising field of forensic odontology. DAVID and WinID3 programs offer a wide range of tools and options that are very useful and should assist forensic odontologists in the matching process. Some of the main features are listed in Table 2.

The present study was designed to assess the behaviour of both programs when used following a disaster that is characterized by sparse antemortem data and fragmented postmortem remains in most of the cases studied. The DVI training set used was not intended for dental identification alone, but for training other DVI disciplines and hence the manual dental method succeeded in matching approximately 55% of the cases on its own which is slightly less than would be expected in daily forensic dental identification cases.[22]

An important advantage of the computer-aided dental identification methods that probably would prevail over the manual matching is its use as a missing persons database whereby antemortem dental records are stored and any discovered dental remains can then be matched quickly to that antemortem bank of dental characteristics.[24,26] Both programs offer this option through their respective targeted search.

CONCLUSION

In this study, DAVID and WinID3's performance was less accurate by comparison with the more time-consuming classical manual matching method. Although both programs have different methods of matching antemortem and postmortem dental characteristics, the difference between DAVID and WinID3 was not significant. At the present time computers can assist with the initial sorting of records with confirmation made by manual method. Further improvement is clearly required to facilitate data entry and to produce more accurate matching outcome.

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