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TECHNICAL NOTE

ODONTOLOGY

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Usefulness of Forensic Dental Symbols© and Dental Encoder© Database in Forensic Odontology*

ABSTRACT: A new universal graphic dental system, Forensic Dental Symbols©, has been created to provide precision in the construction of dental records, improve standardization, and increase efficiency in dental identification procedures. Two hundred and thirty-four different graphic symbols representing the most frequent clinical status for each tooth were designed. Symbols can be then converted to a typographic font and then are ready to use in any computer. For the appropriate use, manipulation, and storage of dental information generated by the Forensic Dental Symbols©, Dental Encoder© database has been created. The database contains all the information required by INTERPOL Disaster Victim Identification (DVI)-dental-forms. To explore the possibilities that Dental Encoder© offers, an antemortem dental database from a Spanish population of 3920 military personnel had been constructed. Data generated by Dental Encoder© were classified into sex and age groups. The program can perform an automatic search of the database for cases that match a selected clinical status presented in a single tooth or a combination of situations for several teeth. Moreover, Dental Encoder© allows information to be printed on INTERPOL DVI-dental-forms, or the inclusion of any completed form into any document, technical report, or identification of dental report.

KEYWORDS: forensic science, forensic odontology, dental identification, dental records, dental symbols, standardization

In the event of any major disaster, the application of quality management guidelines for Disaster Victim Identification (DVI)-ISO/IEC 17025 issued by INTERPOL (1) is highly recommended. Identification procedures that follow these guidelines serve to guarantee a scientifically based identification of victims that complies with legal requirements within any worldwide jurisdiction.

Dental identification is based on the comparison of postmortem dental records obtained by the forensic odontologists with the antemortem records of missing victims. Currently, these are constituted using odontograms and other dental data, such as oral radiographs, photographs, or dental casts. An important and often underestimated process in DVI is the gathering of the antemortem data of reported missing persons (2). However, a major difficulty facing the forensic odontologist is the correct display and interpretation of the antemortem dental data supplied by dentists. This inconvenience has mainly arisen because of a lack of consensus on what dental codes should be used to represent specific characteristics or treatments. Traditionally, individual dental practices tended to use their own particular coding systems for the creation of clinical records; the collection of data was in some cases manual and in others, but to a lesser degree, not even stored in a computerized form. However, even when records have been computerized, they are often created by specific software programs designed to meet the requirements of individual dental practices or companies. In such cases, independently created codifications are used to describe tooth pathologies and treatments.

The main goal for forensic odontologists, when working as members of the postmortem DVI-team, is to give a detailed and accurate description of the dentition and surrounding structures, so as to be able to make comparisons with evidence from antemortem dental records (3). On occasions, a large number of forensic dentists from different nations may be involved in this process, making an effective exchange of information and a uniform interpretation of dental data essential (4). Successful international cooperation therefore largely depends on the creation of a common standardized nomenclature as the basis for an effective exchange of information.

The American Dental Association (ADA) has developed a system of descriptive dental codes, the Systematized Nomenclature of Dentistry (SNODENT) (5). SNODENT is a comprehensive taxonomy that contains codes for identifying not only diseases and diagnoses, but also anatomy, clinical conditions, morphology, and social factors that may affect health or treatment (6). See the Appendix for an explanation of acronyms and abbreviations. In forensic dentistry, several dental data coding systems have been proposed for the use in reports and computer-assisted identifications (7,8). The most well-known identification applications in the electronic management of dental records are CAPMI® (9) (US Army Institute of Dental Research), WinID® (10) (American Board of Forensic Odontology), "DAVID web" (11), or the Plass Data DVI® (12) (PLASS DATA Software, Holbaek, Denmark). All have been recommended by INTERPOL to its member countries, but while they share a common purpose, none allow an effective interchange of information, because of the use of different encoding systems for the cataloging, display, and storage of dental records data.

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As a consequence, a major challenge in forensic dentistry for both antemortem and postmortem DVI-teams is to establish a single forensic coding system that allows treatments or the clinical status of each tooth to be universally identified. The use of universal forensic dental coding system will provide precision in the creation of records, improve standardization, increase efficiency, and guarantee higher quality standards in identification procedures. Moreover, the design of dental codes for forensic purposes has been encouraged by forensic odontology associations and especially by the INTERPOL Standing Committee on Disaster Victim Identification, which concluded that among other issues, standardization is the key to guaranteeing an effective response to any major mass disaster (2–13).

The main aim of this study was to present and discuss a universal dental system Forensic Dental Symbols© (2010, University of Granada, Department of Forensic Medicine and Forensic Odontology, Granada, Spain) created in a format compatible with most of the currently available identification softwares.

Forensic Dental Symbols© was constructed using the Unicode® Standard (14). The Unicode® Standard is the universal character encoding system used for representing text in computer processing. Unicode© is developed in conjunction with the International Organization for Standardization and shares the character repertoire with ISO/IEC 10646: 2003, which defines the Universal Character Set (UCS). The Unicode® Standard provides additional information on graphic characters and their usage. As a character coding system, it was designed to support the worldwide interchange, processing, and display of written texts in diverse languages and technical disciplines of the modern world and has provided a common reference for alphabetic characters, ideograms, and symbols. Unicode® was created to achieve three objectives: universality, uniformity, and uniqueness. The basic component of the Unicode® Standard is the *character*, considered the smallest element in a written language having semantic value; a unit of information used for the organization, control, or representation of textual data. The Unicode® Standard includes alphabetic scripts, punctuation marks, diacritics, mathematical symbols, technical symbols, arrows, and dingbats. Unicode® provides a unique number for every character, called *code point.* For convenience, all the space for codes that makes up the UCS has been divided into 17 large groups known as planes. The UCS includes 137,468 code points distributed among plane 0 (E000-F8FF), and planes 15 and 16, designated for private use. This Private Use Area (PUA) is reserved for private definition and used for creating proprietary, nonstandard character definitions, outside the ISO and Unicode Consortium. It is relatively easy for input method editors to allow private use characters to be added in the PUA. With modern font technologies, these characters can also be added to fonts for display and printing.

On the other hand, another two important objectives in this research were first to create a database for the appropriate use and manipulation of dental information generated by Forensic Dental Symbols©, through the creation of Dental Encoder© (2010, University of Granada, Department of Forensic Medicine and Forensic Odontology, Granada, Spain) and second, to construct an antemortem dental database from a Spanish military population, using Dental Encoder©.

Methods

Forensic Dental Symbols©

Forensic Dental Symbols© was created using a typographic font in TrueType® Format (TTF). Two hundred and thirty-four different graphic symbols were designed and assigned to a specific area (from U+E000 to U+E0E9 code points of plane 0) of the UCS. The system also allows for the design of new symbols for up to 6400 different characters, in the space reserved for private use in plane 0 of the UCS.

The graphic symbols represent the crown or the root of each tooth and each character contains a complete and detailed amount of information on the most common clinical status and treatments, as well as, data concerning pathologies, filling materials, prosthesis, etc. Graphic symbols for teeth are based on the INTERPOL DVI-form, while End User Defined Characters Editor (EUDCEDIT) was used in the design of all the graphic symbols. EUDCEDIT is an editor for the creation and design of unique characters, available in all Microsoft Windows environment computers. An easy and user-friendly interface allows users to fill up the appropriate number of pixels of a 64 × 64 structure, creating the basic graphic symbol for a posterior or anterior tooth (Fig. 1) or its root outline. Posterior teeth were represented by a square outline divided into five dental surfaces such as Mesial, Distal, Vestibular, Lingual, and Oclusal, whereas only four dental surfaces (M, D, V, and L) were drawn for the anterior teeth. An odontogram composed of basic

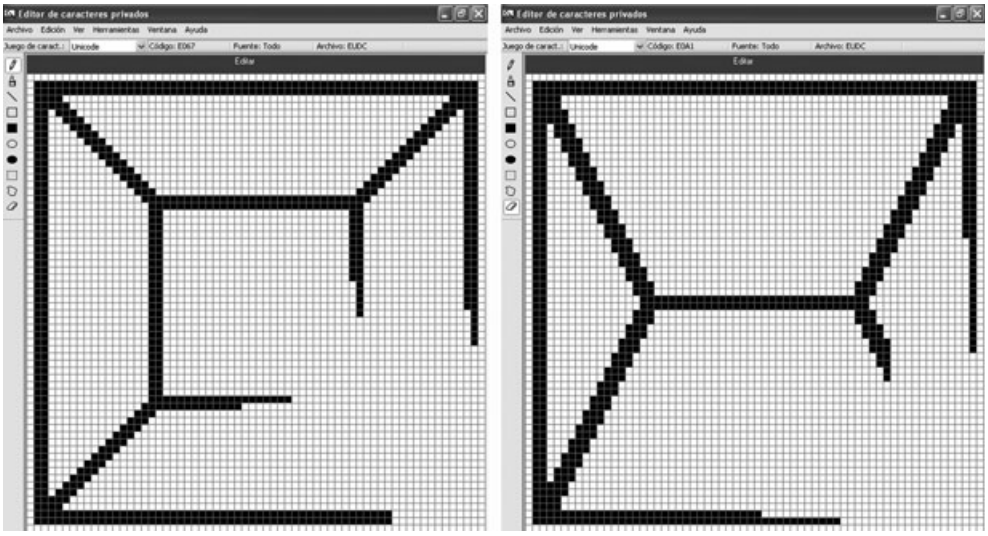

FIG. 1—*Design of dental crowns from posterior (left) and anterior (right) teeth.*

dental graphic symbols, based on the INTERPOL DVI-form and teeth named according to Fédération Dentaire Internationale (FDI) notation (15), was subsequently created (Fig. 2).

Diverse characters were added to each basic dental graphic symbol, thus creating a new dental symbol for every possible clinical status for each tooth, together with the possibility of including characteristics such as sound, carious, filled, crown, remaining root, lost postmortem, or missing antemortem. Unique dental codes for restored and prosthetic teeth and characters for the material used and surface(s) involved were also constructed. Two hundred and thirty-four different graphic symbols where created and examples of those symbols and textures used to represent carious dental surfaces and the type of restorative material are illustrated in Fig. 3. Briefly, caries is represented by bold black lines around the affected dental surface(s); amalgam fillings by solid black colored areas; tooth color filling materials by fine black lines; and a gold restoration by a spotted black area (Fig. 3*A*). The symbol for crown restorations is a solid bold black outline around the crown, plus a specific texture, representing the restoration material used (metal, porcelain, gold, or porcelain fused to metal) in the inner portion (Fig. 3*A*). Other symbols for conditions such as missing antemortem, missing postmortem, pontic, unerupted tooth, partially erupted, impacted tooth, fractured tooth, retained root, enamel sealant, or no information available were also created (Fig. 3*B*). Graphic symbols for the most frequent root treatments (root canal treatment, post, implant or missing root) are also included (Fig. 3*C*).

Once all the characters have been designed and edited, the system automatically creates an EUDC.tte file, which can be saved into the font folder. Conversion to a typographic font in TTF is performed by renaming and changing the file extension to Forensic Dental Symbols.ttf. The fonts are then ready to use, while font properties can be modified using any type of font editor.

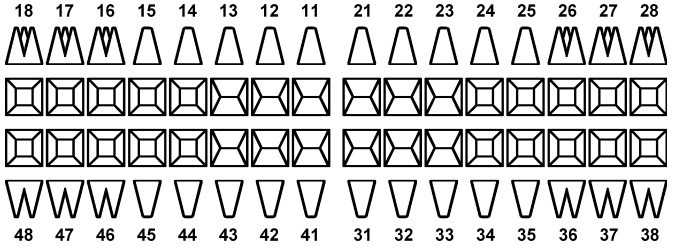

FIG. 2—*Odontogram composed of basic dental graphic symbols based on the INTERPOL Disaster Victim Identification (DVI)-forms. Teeth are named according to Fédération Dentaire Internationale notation (15).*

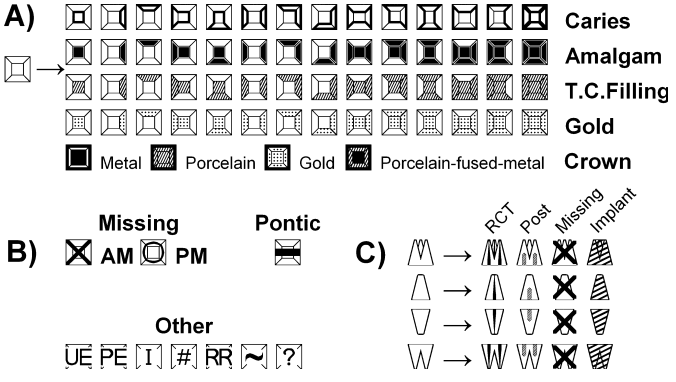

FIG. 3—*Examples of symbols and textures used in Forensic Dental Symbols©. (A) Caries, filling materials and crown restorations. (B) Missing antemortem, missing postmortem, pontic, and other. (C) Root symbols: Root Canal Treatment (RCT), Post, Missing root, Implant.*

Dental Encoder© Database

Dental Encoder© is a database designed specifically for the appropriate use, manipulation, and storage of dental information generated by Forensic Dental Symbols©. Dental Encoder© was developed in a Microsoft Windows environment using Microsoft® Office Access (Microsoft Corporation, Redmond, WA) and contains information required by INTERPOL DVI-dental-forms, which in the case of Ante-Mortem forms, includes the following entities: antemortem details from the missing person and dentist odontogram details, represented by characters and dental graphic symbols used by Forensic Dental Symbols©. Other types of complementary information, such as photographs or radiographs may also be incorporated into the database. The Access database created has text (name and surname, sex, citizenship, comments, and dental symbols), numeric references (case number, identification card or passport number, and date of birth), and image format fields (photographs and radiographs in *.jpg format).

The program can be opened by clicking on an icon from which one of the three possible languages (Spanish, English, or French) can be chosen. An AnteMortem form, presented in yellow, modeled on section F2 of the INTERPOL DVI-form, will then open on the screen (Fig. 4). Basically, Dental Encoder© uses a graphical user interface that keeps the typing of text to an essential minimum and much of the operation of the program is "mouse" driven, that is, point-and-click.

Information on the clinical status of the crown can be introduced by selecting each individual tooth, after which a new window will open, providing data on the following clinical situations: caries, amalgam, tooth colored filling, gold, crown, missing, and other. The user may click on either of the mentioned clinical status and subsequently select from the lists of surfaces filled or treated (Fig. 4). Notes per tooth are automatically entered into the boxes above and below the tooth chart, one box per quadrant, one line per tooth. In addition, dental graphic symbols in the odontogram are generated automatically once the selection of the clinical status has been made. After entering the crown clinical status, root information can be included into the form by selecting any of the following clinical situations: root canal treatment, post, missing, and implant. Errors in completing the odontogram may be corrected by clicking again on the selected tooth and reentering the new data.

System Requirements

The minimum hardware required by Forensic Dental Symbols© is a personnel computer with 640K of RAM; or a Macintosh computer with a minimum of 2 MB of RAM, and 155 KB of hard disk space. Dental Encoder© requires a personnel computer with a minimum of 133-MHz processor with 64 MB RAM, Super VGA screen resolution (800 × 600 resolution with 256 colors), mouse and 5 MB hard disk space.

Spanish Military Dental Database by Dental Encoder©

Before international missions, Spanish military personnel are given medical and dental examinations, through which data for possible posterior identification are routinely collected. This information includes an anthropometric form and photograph, a biological sample (blood) for DNA investigation, and a complete dental record. The study was conducted in accordance with the ethical standards laid down by the Declaration of Helsinki.

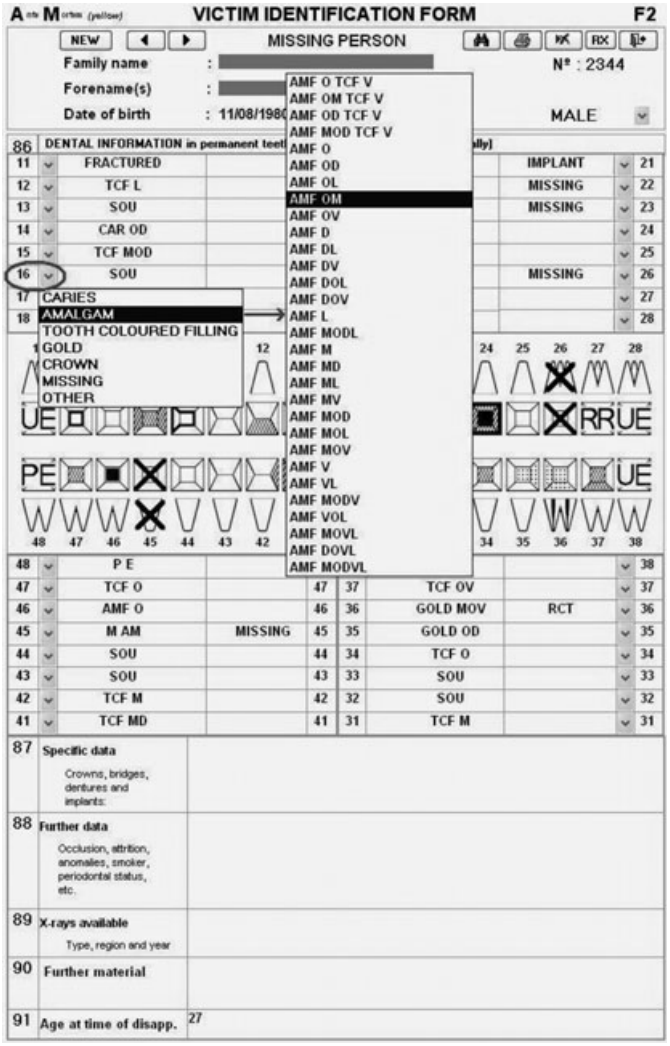

FIG. 4—*Dental Encoder© database for AnteMortem data entry modeled on section F2 of the INTERPOL Disaster Victim Identification (DVI)-form.*

For our purposes, all the dental and oral examinations were performed by one single odontologist for a population of 3920 military personnel. The age range of the population was 18–55 years; 12% of the sample was female. The dental data obtained were subsequently introduced into Dental Encoder© database.

Results and Discussion

When a mass disaster occurs, no matter where, it provides an opportunity for the international agreement and cooperation among forensic dentists from all over the world. In this respect, there is worldwide agreement within the forensic dentist scientific community on the need for a universal dental coding system for forensic purposes (2,13). Although several dental coding systems already exist, none are universally accepted. As an example, the simple FDI notation for numbering teeth is not applied on a worldwide scale (15).

Forensic Dental Symbols© and Dental Encoder© have been designed to contribute to the construction of a universal system for transcription, manipulation, and storage of dental symbols for forensic dentists. The first, Forensic Dental Symbols©, includes graphic symbols for teeth based on the INTERPOL DVI-forms. At this moment in time, 234 different dental symbols have been designed to cover the most frequent treatments and clinical tooth situations, but these designs can be easily modified or additional symbols can be created upon international consensus among forensic dentists. Moreover, these dental graphic symbols are easily remembered and do not require excessive previous training of forensic dentists.

To avoid possible misinterpretations of faxed or photocopied records and to permit a more straightforward international exchange of information, all dental symbols have been created using the color black only, with different shades and textures to represent the most common restorative materials (Fig. 3). The specific clinical status of each tooth surface can also be documented. As recommended by the German Association of Forensic Odontostomatology (16), information on the clinical status of each dental root may be of interest for dental identification purposes and has therefore been included into Forensic Dental Symbols© (Fig. 3*C*).

Once the file containing Forensic Dental Symbols© has been installed as a font on a computer, special dental characters can be selected from any character map utility as the Microsoft Windows CHARMAP, while at the same time, these characters may also be used as symbols or included in any text document (Fig. 5). Forensic Dental Symbols© can therefore be interpreted and is compatible with most of the currently available systems and software applications (Fig. 5). Additional information regarding Forensic Dental Symbols© could be available on demand at: http://www.ugr.es/local/agarach/forensicdentalsymbols.

The Dental Encoder© database was constructed, using the graphic possibilities that Microsoft Office Access offers for entering and visualizing data. An AnteMortem form, modeled on section F2 of the INTERPOL DVI-yellow form, can be created for each individual case (Fig. 4), and subsequently printed. Dental Encoder© also allows the generation of the PostMortem INTERPOL DVI-pink form, by introducing the data in the same manner as previously described for the AnteMortem INTERPOL DVI-yellow form.

Dental Encoder© could be used for the generation of a dental database for missing persons or nonidentified victims in mass disasters. Dental data generated by Dental Encoder© can be classified into sex or age groups. The program can perform an automatic search of the database for cases that match a selected clinical status presented in a single tooth or a combination of situations for several teeth. Moreover, Dental Encoder© allows information to be printed on INTERPOL DVI-dental-forms, or the inclusion of any completed form into any document, technical report, or identification dental report.

To explore the possibilities that Dental Encoder© offers, an antemortem Spanish military population dental database was created and subsequently analyzed. The sample was classified into eight age groups, whose demographic and dental characteristics are shown in Table 1. The original detailed dental clinical status was condensed into four categories, according to the international rules for forensic research (17): *Unrestored* teeth were composed of sound, decayed, fissure sealants, partially erupted teeth, or retained root; *Restored* teeth included all type of fillings; *Crown* included bridge abutment or special crown prostheses; and *Missing* teeth were absent or unerupted on visual examination. A significant association ($p < 0.001$) was found to exist between dental clinical status or dental characteristics and age groups. For example, *unrestored* was the most frequent dental characteristic in younger adults (18–37 years), whereas *missing* was found more frequently in older adults (38–57 years).

The study of dental patterns and dental clinical status diversity is another area of recent interest in forensic dentistry (17–19). Moreover, there is still considerable debate on the qualitative or

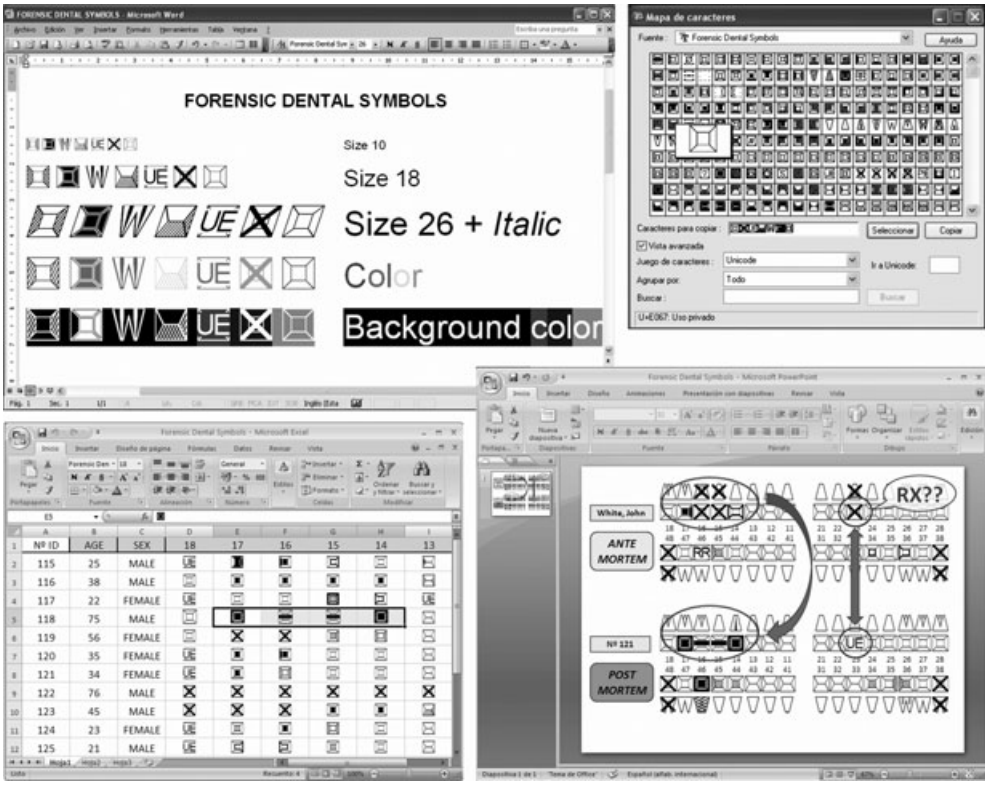

FIG. 5—*Use of Forensic Dental Symbols© with different software.*

TABLE 1—*Demographic data and dental clinical status of the eight age groups from the Spanish military population database.*

	18–22 (n = 1054)	23–27 (n = 1145)	28–32 (n = 832)	33–37 (n = 407)	38–42 (n = 187)	43–47 (n = 186)	48–52 (n = 88)	53–57 (n = 21)
Age (years) (mean ± SD)	20.4 ± 1.2	25 ± 1.4	29.8 ± 1.4	34.6 ± 1.4	40 ± 1.4	44.6 ± 1.4	49.3 ± 1.2	53.7 ± 0.7
Sex (% male)	86.24	81.92	87.02	95.58	98.40	98.92	100.00	100.00
Dental clinical status (%)*,†								
Unrestored	84.39	80.79	75.56	72.11	68.05	61.21	60.37	52.08
Restored	7.55	10.63	13.77	15.39	16.53	16.35	15.02	9.67
Crown	0.28	0.65	1.58	2.51	2.46	6.18	7.85	6.55
Missing	7.78	7.93	9.09	10.00	12.97	16.26	16.76	31.70

*The percentage distribution refers to the complete dentition (32 teeth).

†*Unrestored* teeth consisted of sound, decayed, fissures sealants, partially erupted teeth, or retained root; *Restored* teeth included all type of fillings; *Crown* included bridge abutment or special crown prosthesis; and *Missing* teeth were absent or unerupted on visual examination.

quantitative assessment of forensic examination results, including the need for introducing a more solid scientific basis for dental identification (20). Both Forensic Dental Symbols© and Dental Encoder© database will make a significant contribution to the improvement of dental data classification and analysis. However, further statistical treatment of dental datasets from different populations is required, to obtain more definitive findings on the reliability of dental identification procedures.

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Appendix

Acronyms and abbreviations used in the text, tables, and figures.

Categories	Acronym	Meaning
Dentistry	ADA	American Dental Association
	AMF	Amalgam Filling
	PE	Partially Erupted tooth
	RCT	Root Canal Treatment
	RR	Retained Root
	SNODENT	Systematized Nomenclature of Dentistry
	SOU	Sound tooth
	TCF	Tooth Colored Filling
	UE	Unerupted tooth
Standards and Characters	CHARMAP	Character Map
	EUDCEDIT	End User Defined Characters Editor
	IEC	International Electrotechnical Commission
	ISO	International Organization for Standardization
	PUA	Private Use Area
	UCS	Unicode Character Set
	UNICODE	Universal Character Encoding Standard
	TTF	True Type Format