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SECTION IDENTIFICATION

ASSESSMENT OF THE UNIQUENESS OF HUMAN DENTITION

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ABSTRACT
Comparing ante-mortem and post-mortem dental characteristics has been a reliable, accurate and quick human identification method. This is based on the assumption that each individual's set of teeth is unique; however, there is little evidence to support this assumption. This research aimed to determine the uniqueness of basic dental features in a cohort of multinational dental patients.
Dental charts were retrieved from the archives of the College of Dentistry at the University of Sharjah. Dental patterns were coded into letters representing basic dental characteristics, and entered into a computer program that was written specifically for analysing the results of this research.
Two thousand dental charts were included in this research; the average age of the sample was 31.9 years (11–87 years). The male:female ratio was 1.4:1 from 55 nationalities. One thousand one hundred and fifty-nine dental charts (57.95%) had absolutely unique dental patterns. The remaining charts (n=841 [42.05%]) were found to have identical patterns with others, the most common of which was 'all virgin' teeth (n=482 [24.1%]). Introducing a single dental modification dropped this percentage to 1.05%. This percentage was further narrowed down to 0.7% when the gender variable was introduced to the comparison.
The results of this research support the assumption that dental characteristics show a diversity that is useful for human identification, even when those characteristics are recorded in their simplest forms.

KEYWORDS**:** *forensic odontology; dental diversity; dental uniqueness; dental pattern; human identification*

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INTRODUCTION

Accurate human identification is of utmost importance for humanitarian, legal and social reasons. Identification of human remains can be achieved reliably by comparing certain human characteristics recovered from post-mortem remains with their counterparts collected from presumed missing persons. The human characteristics that are considered to be scientifically acceptable identifiers are fingerprints, DNA profile and medical and dental characteristics.[1,2]

Among these, dental characteristics are special because of the durability of dental tissues, which can withstand extreme perimortem and post-mortem conditions, such as decomposition, extensive trauma and intense heat.[3] This unique durability is extended to dental restorations and prostheses, which are manufactured to simulate natural dental robustness, and are therefore resistant to destruction by biological, chemical and physical challenges.[4,5]

Dental identification has proved to be the quickest and most successful method of identification in mass disasters where victims had dental records to acceptable professional standards. However, in other disasters the reported percentage is much lower due to unavailable, incomplete and/or inaccurate ante-mortem dental data.[6–14]

The use of dental characteristics in human identification in the Middle East is relatively new. There are sporadic cases reported from different countries, but the only report was found in English language literature.[14] A major challenge to forensic odontologists in this region is the absence of specifically written policies and guidelines that govern the quality of dental records and the extent of information that should be included in the dental chart.

The uniqueness of dental characteristics and how frequently certain dental modifications are found in a community have been the focus of various research papers. For example, Adams concluded that the diversity in dental patterns is large enough to identify persons even in the absence of dental radiographs. His study relied on a simple dental chart comparison of missing, restored and unrestored teeth.[15] Furthermore, dental characteristics were validated as being comparable to mitochondrial DNA as a method of human identification.[16] Diversity was observed at two levels: the morphological uniqueness of human dentition and the uniqueness of dentition after dental treatment intervention even when the genetic characteristics were the same, as in the case of identical twins.[17]

Disasters often involve victims of multiple nationalities and one of the major challenges facing identification teams is the ability to collect ante-mortem data of sufficient detail to be used for a meaningful comparison. The diversity of dental characteristics of a multinational post-mortem population has not been previously studied. Therefore, the aim of the study was to determine dental diversity, in its simplest possible form, in a multinational population sample.

MATERIALS AND METHODS

SAMPLE AND MATERIAL

A total of 6400 dental records archived at the College of Dentistry at the University of Sharjah were randomly selected and screened for inclusion in this study. Inclusion criteria included patients who were registered in the archives of the College of Dentistry academic dental centre and had signed the consent form, and whose dental charts were complete and signed by a fourth- or fifth-year dental student and by the supervising faculty member. Patients were offered comprehensive treatment after full dental charting. Dental records with incomplete demographic information, with primary or mixed dentition charts and with persistent deciduous dentition and/or illegible dental charts, were excluded. Information about age, gender and nationality was extracted and collected.

CODING

Dental characteristics recorded in the dental charts were converted into simplified dental codes according to Adams (2003).[15] Codes were put into two separate data sets: detailed and generic (Table 1).

FDI notation was used for dental charting. Dental characteristics were recorded as follows: teeth that were not restored or decayed, retained roots were coded as ‘V’ in both detailed and generic formats. Teeth that were restored with any type of dental material were coded as ‘R’ in the generic format. In the detailed format,

TABLE 1 – Dental Codes for all dataset with description

Condition	Detailed Format	Generic Format
Anterior restoration	M,D,F,L	R
Posterior restoration	M,O,D,F,L	R
Anterior crown/Implant/Bridge abutment	MDFL	C
Posterior Crown/Implant	MODFL	C
Missing tooth	X	X
Bridge pontic	XP	XP
Unrestored / active decay	V	V

TABLE 2 - Sample size and demographic composition of the detailed and generic data Database (N =2000; Male n=1198 (59.9%), Female n=802 (40.1%)

Age		Region & Nationality											
Range	n(%)	Middle East (n=846)42.3%		North Africa (n=251)12.5%		South & East Asia (n=796)39.8%		South & East Africa (n=45)2.25		North America (n=35)1.75%		Europe & Australia (n=27) 1.35	
11-14	30(1.5%)	UAE	244	Egypt	171	Pakistan	337	Somalia	11	USA	25	UK	9
15-19	114(5.7%)	Palestine	173	Sudan	56	India	156	Ethiopia	8	Canada	10	Russia	4
20-24	484(24.2%)	Jordan	113	Algeria	8	Philippenes	123	Kenya	6			France	2
25-29	417(20.85%)	Syria	104	Morrocco	7	Bangladish	56	Nepal	5			Shishan	2
30-34	282(14.1%)	Iraq	98	Libya	5	Iran	40	Nigeria	5			Australia	2
35-39	208(10.4%)	Yemen	36	Tunisia	3	Indonesia	32	Chad	3			Belgium	1
40-49	278(13.9%)	Lebanon	31	Arteria	1	Afghanistan	27	South Africa	2			Finland	1
50-59	142(7.1%)	KSA	15			Srilanka	19	Cameroon	2			Germany	1
60-69	37(1.85%)	Oman	12			Malaysia	6	Mali	1			Ireland	1
70-87	8(0.4%)	Kuwait	10					Dijibouti	1			Italy	1
		Qatar	5					Tanzania	1			Poland	1
		Bahrain	4									Netherland	1
		Turkey	1									NewZealand	1

restored teeth were coded based on the surface(s) being restored. The surfaces were coded with the initial of each surface, for example 'M' for the mesial surface and 'O' for the occlusal surface. Accordingly, there were five surfaces for posterior teeth (M, O, D, F, L) and four surfaces for anterior teeth (M, D, F, L).

Multiple restorations on a single surface of a tooth were assigned only a single code. For example, two distinct occlusal restorations were coded as 'O' in the detailed format and 'R' in the generic format. A single restoration that affects multiple surfaces or separate restorations on different surfaces of the tooth was given the same code. For example, either a mesio-occlusal single restoration or two distinct mesial and occlusal restorations were coded the same as 'M, O' in the detailed format and collapsed into 'R' in the generic format. If a tooth surface was both carious and restored, it was coded as restored.

TABLE 3–Generic-format with 28 teeth N=2000
The thirteen most frequent dental patterns from the generic data

	Dental pattern (excluding the 3rd molars)			Male		Female	
	Dental pattern	Number (n)	Percent (%)	Number (n)	Percent (%)	Number (n)	Percent (%)
1	V V V V V V V V V V V V V V V V V V V V V V V V V V V V	482	24.1%	335	16.75%	147	7.35%
2	V V V V V V V V V V V V V V V **R** V V V V V V V V V V VV	27	1.45%	18	0.9%	9	0.45%
3	V V V V V V V V V V V V V V V V V V V V V V V V V V **R** V	24	1.2%	12	0.6%	12	0.6%
4	V V V V V V V V V V V V V V VV V V V V V V V V V **X** V	21	1.05%	14	0.7%	7	0.35%
5	V **R** V V V V V V V V V V V V V V V V V V V V V V V V V V	20	1%	14	0.7%	6	0.3%
6	V V V V V V V V V V V V V V V **X** V V V V V V V V V V V V	17	0.8%	11	0.55%	6	0.3%
7	V V V V V V V V V V V V V V V **R** V V V V V V V V V **R** V	13	0.6%	6	0.3%	7	0.35%
8	V V V V V V V V V V V V V V V V V V V V V V V V V **R R**	12	0.6%	8	0.4%	4	0.2%
9	V V V V V V V V V V V **X** V V V V V V V V V V V V V V	12	0.6%	8	0.4%	4	0.2%
10	V V V V V V V V V V V V V V V **X** V V V V V V V V V **X** V	10	0.5%	4	0.2%	6	0.3%
11	**X** V V V V V V V V V V V V V V V V V V V V V V V V V V	9	0.45%	5	0.25%	4	0.2%
12	V **X** V V V V V V V V V V V V V V V V V V V V V V V V V	9	0.45%	7	0.35%	2	0.1%
13	V V V V V V V V V V V **R** V V V V V V V V V V V V V V	9	0.45%	6	0.3%	3	0.15%
	Number of patterns with matches	117 (969 charts)	48.45%				
	Unique dental patterns/charts	1031	51.55%				

TABLE 4 –Detailed-format with 28 teeth N=2000
The thirteen most frequent dental patterns from the Detailed data

	Dental pattern(excluding the 3rd molars)			**Male**		**Female**	
	Dental Pattern	Number (n)	Percent (%)	Number (n)	Percent (%)	Number (n)	Percent (%)
1	V V V V V V V V V V V V V V V V V V V V V V V V V V V V V V	482	24.1%	335	16.75%	147	7.35%
2	V V V V V V V V V V V V V V V V V V V V V V V V V V V **X** V	21	1.05%	14	0.7%	7	0.35%
3	V V V V V V V V V V V V V V V V V V V V V V V V V V V **O** V	17	0.85%	7	0.35%	10	0.5%
4	V V V V V V V V V V V V V V V V **O** V V V V V V V V V V V V V	17	0.85%	11	0.55%	6	0.3%
5	V V V V V V V V V V V V V V V V **X** V V V V V V V V V V V V V	17	0.85%	11	0.55%	6	0.3%
6	V V V V V V V V V V V V **X** V V V V V V V V V V V V V V V V	12	0.6%	8	0.4%	4	0.2%
7	V V V V V V V V V V V V V V V V **X** V V V V V V V V V V **X** V	10	0.5%	4	0.2%	6	0.3%
8	V **O** V V V V V V V V V V V V V V V V V V V V V V V V V V V V	10	0.5%	6	0.3%	4	0.2%
9	V V V V V V V V V V V V V V V V V V V V V V V V V V V **O O**	9	0.45%	5	0.25%	4	0.2%
10	V V V V V V V V V V V V V V V V **O** V V V V V V V V V V **O** V	9	0.45%	3	0.15%	6	0.3%
11	**X** V V V V V V V V V V V V V V V V V V V V V V V V V V V V V	9	0.45%	5	0.25%	4	0.2%
12	V **X** V V V V V V V V V V V V V V V V V V V V V V V V V V V V	9	0.45%	7	0.35%	2	0.1%
13	V V V V V V V V V V V V V V V V V V V V V V V V V V V V V**X**	8	0.4%	4	0.2%	4	0.2%
	Number of patterns with matches	91 (841 charts)	42.05%				
	Unique dental patterns/charts	1159	57.95%				

Dental prostheses were coded as follows: a crown, implant and/or bridge abutment was assigned the code 'MODFL' if the tooth was posterior and 'MDFL' if the tooth was anterior in the detailed format, and 'C' in the generic format. A missing tooth, whether replaced by removable prosthesis or not, was coded as 'X' in both formats and a bridge pontic was coded as 'XP' in both formats.

DATA ANALYSIS

Data collected from dental charts were entered as codes into a Microsoft Excel® spreadsheet (Microsoft Corporation, Redmond, Washington) from which demographic distribution and frequencies were calculated. In order to facilitate comparison between each set of codes of every dental chart with all remaining charts, computer software based on Microsoft Visual Basic C++® (Microsoft Corporation, Redmond, Washington)was specifically designed by the University of Sharjah Computer Programming Unit to be used for this research.

The software was set to yield four different sets of results. The first screening was to compare the generic and detailed codes (separately) of every dental chart with all other charts and to filter out charts with identical sets of codes. Then, another screening was performed in both the generic and detailed formats to reveal charts with identical premolar and molar codes (excluding anterior teeth).

Another use of the software is to compare randomly chosen sets of codes against all other charts in either format to find identical matches and then filter that out by adding information about age, sex and nationality.

RESULTS

Two thousand dental charts satisfied the inclusion criteria. The age of the sample

TABLE 5– Generic-format with 16 teeth N=2000
The thirteen most frequent dental patterns from the generic data

	Dental pattern (Molars & Premolars)			**Male**		**Female**	
	Dental pattern	Number (n)	Percent (%)	Number (n)	Percent (%)	Number (n)	Percent (%)
1	V V V V V V V V V V V V V V V V	523	26.15%	363	18.15%	160	8%
2	V V V V V V V V V V V V V V **R** V	30	1.5%	15	0.75%	15	0.75%
3	V V V V V V V V V **R** V V V V V V	30	1.5%	20	1%	10	0.5%
4	V V V V V V V V V **X** V V V V V V	21	1.05%	14	0.7%	7	0.35%
5	V V V V V V V V V V V V V V **X** V	21	1.05%	14	0.7%	7	0.35%
6	V **R** V V V V V V V V V V V V V V	20	1%	14	0.7%	6	0.3%
7	V V V V V V V V V **R** V V V V **R** V	14	0.7%	7	0.35%	7	0.35%
8	V **X** V V V V V V V V V V V V **V** V	12	0.6%	8	0.4%	4	0.2%
9	V V V V V V **X** V V V V V V V V V	12	0.6%	8	0.4%	4	0.2%
10	V V V V V V V V V V V VV V **R R**	12	0.6%	8	0.4%	4	0.2%
11	V V V V V V V V V **X** V V V V **X** V	12	0.6%	4	0.2%	8	0.4%
12	**X** V V V V V V V V VV V V VV V	11	0.55%	7	0.35%	4	0.2%
13	V V V V V V V V V V V V V V V **X**	10	0.5%	6	0.3%	4	0.2%
	Number of patterns with matches	124 (1056 charts)	52.8%				
	Unique dental patterns/charts	944	47.2%				

ranged from 11 to 87 years old (average=31.9). The male (n=1198) to female(n=802) ratio was 1.4:1.The sample covered55 nationalities, and most of those nationalities (54.8%) came from the Middle East and North Africa (MENA) region (Table 2).

When comparing the set of codes of every dental chart with all other charts for 28 teeth,1031 dental charts had absolutely unique dental patterns based on their generic codes (51.55%). This percentage increased to 57.95% when the detailed codes were assessed (Tables 3 and 4). The remaining dental charts had repeated patterns. The most common of those repeated patterns was 'all virgin' teeth, which was seen in 482 (24.1%) charts in both the generic and detailed formats.

However, when a single dental modification was introduced (restoration or extraction), the percentage of dental charts that shared the same patterns dropped to 1.45% and 1.05% in the generic and detailed formats respectively. This percentage was further narrowed down to 0.9% and 0.7% respectively when the sex variable was introduced to the comparison.

When anterior teeth were eliminated from the analysis, 944 (47.2%) dental charts showed unique dental patterns based on their generic codes, and this number increased to 1064 dental charts (53.2%) when the comparison included the detailed codes. The most repeated pattern in the remaining charts was the 'all virgin' teeth (n=523 [26.15%]) in the detailed and generic codes formats (Tables 5 and 6).

The most common tooth to demonstrate a dental characteristic (whether restored, crowned or missing) was the lower first molar.

DISCUSSION

The dental record, also referred to as the patient's chart, is the official office document that records all treatments carried out and all patient-related communications that occur in the dental office. Normally, countries have

TABLE 6–Detailed-format with 16 teeth N=2000
The thirteen most frequent dental patterns from the Detailed data

	Dental pattern (Molars & Premolars)			Male		Female	
	Dental pattern	Number(n)	Percent (%)	Number(n)	Percent (%)	Number(n)	Percent (%)
1	V V V V V V V V V V V V V V V V	523	26.15%	363	18.15%	160	8%
2	V V V V V V V V V V V V V V **X** V	21	1.05%	14	0.7%	7	0.35%
3	V V V V V V V V V **X** V V V V V V	21	1.05%	14	0.7%	7	0.35%
4	V V V V V V V V V V V V V V **O** V	20	1.0%	9	0.45%	11	0.55%
5	V V V V V V V V V **O** V V V V V V	19	0.95%	12	0.6%	7	0.35%
6	V **X** V V V V V V V V V V V V V V	12	0.6%	8	0.4%	4	0.2%
7	V V V V V V **X** V V V V V V V V V	12	0.6%	8	0.4%	4	0.2%
8	V V V V V V V V V **X** V V V V **X** V	12	0.6%	4	0.2%	12	0.6%
9	**X** V V V V V V V V V V V V V V V	11	0.55%	7	0.35%	4	0.2%
10	V **O** V V V V V V V VV V V VV V	10	0.5%	6	0.3%	4	0.2
11	V V V V V V V V V **O** V V V V **O** V	10	0.5%	4	0.2%	6	0.3%
12	V V V V V V V V V VV V V VV **X**	10	0.5%	6	0.3%	4	0.2%
13	V V V V V V V V V V V V V V**O O**	9	0.45%	5	0.25%	4	0.2%
	Number of patterns with matches	104 (936 charts)	46.8%				
	Unique dental patterns/charts	1064	53.2%				

laws or regulations that determine how those records are handled, how long they are kept for and who may have access to the information within them.

The dental record provides continuity of care for the patient. It is considered essential for the overall healthcare of each patient, and it constitutes an important legal document in the event of a malpractice claim. Additionally, the information recorded about the conditions of teeth and dental treatments carried out on each tooth is extremely useful in human identification when other methods of identification are either slower, expensive and/or complicated.[1,9] As previously stated, a successful dental identification will depend entirely on how well dental information is documented.

Several studies have investigated the quality of dental recordkeeping from a forensic perspective. They concluded that the quality of dental records is often poor. This is manifested by incompleteness of data, inaccurate and outdated dental information, and not following the standards and guidelines recommended by national dental associations.[18–25] Charting errors can seriously undermine the use of dental records for human identification. For example, Bormann et al found that the most common error was in charting missing teeth and dental restorations, which are the backbone of forensic dental identification.[25]

In the United Arab Emirates, there are no purposely set regulations for guaranteeing the completeness of dental records. Instead, there are general codes found in the various codes of conduct in different emirates. In 2008, a new federal law on medical responsibility was passed that very briefly addressed the issue.[26] The effect this has on the quality of dental records and their usefulness in identification is not known since no studies have investigated the influence of those regulations on dental

practitioners' compliance with good record keeping in the UAE.

Our sample in this study consisted of dental charts extracted from the archives of the College of Dentistry at the University of Sharjah. Those charts were filled in by fourth- and fifth-year dental students, and were then reviewed and corrected under direct academic supervision. The academic setting under which those charts were filled in dramatically reduces the chances of human charting error, and thus makes those charts an accurate representation of patients' dental characteristics.

With the ongoing challenges of poor dental records, it is expected that dental information will not be complete. Therefore, we wanted to find out whether dental information, in its simplest form, can still show human individuality and be useful in human identification

Data analysis was achieved using Microsoft Visual Basic C++®,which is an application programming tool developed by Microsoft® for C++ programmers and simple programs can be written using it. The program written in this study has similar features used in previous studies.[11,15,27] This software can be modified, whereby additional options can be added to obtain more specific information and analyse it, in addition to the possibility of this software being operated internationally as a valuable method for identification purposes.

Our study revealed that detailed and generic dental patterns consisting of 28 teeth are close in their diversity. For example, the percentage of patients found with unique dental patterns (no other similar patterns) using generic codes and detailed codes was 51.55% and 57.95% respectively. This implies that more than half of our sample can be dentally identified, even when their dental information is written in a superficial manner. The remaining patients had dental patterns that were identical to at least one other patient.

Our results also showed that 24.1% of the sample had no previously carried out dental treatments. The 'all virgin' dental charts represent a challenge to forensic odontologists since there are no acquired dental characteristics to be used for comparison. However, a forensic odontologist can still contribute to identification by building a post-mortem profile of the victim including estimating the age at death, opining on anthropological traits such as high concentration of fluoride, occupational dental changes and morphological dental features of teeth and performing photograph-skull superimposition in order to approximate the identity by narrowing down potential matches.[28–30]

Interestingly, we noticed that this percentage drops to 1.45% when a single dental restoration is performed on a tooth and to 1.05% when a single tooth is extracted for generic coding. As for the detailed coding, the percentage drops to 1.05% when a single tooth is extracted and to 0.85% when a single tooth is restored with an occlusal filling. These percentages drop further when gender is introduced as a variable. This implies that dental identification in mass disasters should be coupled with specific demographic information, such as gender and age, in order to aid in identifying victims who have one or two similar dental features.

Frequently, dental identification is required when there are disasters with mass fatalities, and normally the disaster victims would have been subjected to perimortem and post-mortem damages. Being protected by the tongue and cheeks, posterior teeth are known to preserve their structure and characteristics despite extreme fire and extensive trauma. Anterior teeth have less protection and are thus more prone to losing their characteristics. With this in mind, we wanted to find out what the effect of losing all anterior teeth characteristics would be on the overall diversity of dental patterns.

Accordingly, when the 12 upper and lower anterior teeth were eliminated from the analysis, 47.2% and 53.2% showed absolutely unique patterns in the generic and detailed formats respectively. The percentages of those who had 'all virgin' teeth was 26.15% for both formats, which drops to 1.5% and 1.05% in the generic and detailed formats respectively when a single dental treatment is acquired. Hence, dental patterns are still to a large extent individualized, even when only posterior teeth are available for matching.

The lower first molars were the most affected teeth in the sample whether restored, missing or crowned due to the fact that they are the first

permanent teeth to erupt into the oral cavity and accordingly the most affected by caries.

Our study has several points of strength. Firstly, the multinational composition of our sample makes our assessment of dental diversity generalizable and particularly beneficial for assessing the usefulness of using the dental identification method in disasters involving multinational victims. Secondly, the data collection, being performed in an academic setting and checked for accuracy by the academic faculty, strengthens the validity of our results. And thirdly, the use of a purposely designed computer program for dental code comparison eliminates subjectivity and possible human errors.

In conclusion, dental charts are considered a valuable and useful tool in forensic human identification when combined with other characteristics such as age and gender and can lead to constructive identification of unidentified human remains.

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