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Dental Patterns in Peruvians: A Panoramic Radiography Study

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ABSTRACT

The dental pattern is defined as the combination of distinct codes assigned to describe specific tooth conditions including virgin, missing, and restored teeth that comprise the complete dentition or from discrete groups of teeth. This pattern can be then compared to the dentition of individual/s in an attempt to determine positive identification. The aims of the present investigation were to study and determine the diversity of dental patterns in Peruvian citizens based on a sample of panoramic radiographs. Digital panoramic radiographs of 900 adult Peruvian patients (450 female and 450 male) were evaluated to determine the dental patterns. The most frequent dental patterns found in the complete dentition, maxillae, upper-anterior and lower-anterior sextants were all-virgin-teeth (0.3%), all-extracted teeth (1.9%), all-virgin teeth (1%) and all-virgin-teeth (34.2% and 72.3%) respectively. The diversity was calculated by the use of the Simpson´s diversity index, the resulting values for the full-dentition, maxilla and mandible were over the 99.8% value and were similar to those previously reported in the scientific literature. This study demonstrates the positive benefit of dental patterns in the process of identification. Additionally a combination of codes is proposed that could prove useful in cases where a better radiographic description is required.

KEYWORDS**:** Forensic Dentistry, Panoramic Radiograph, Human Identification, Forensic Anthropology

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INTRODUCTION

The process of identification is a prime challenge in forensic science[1]. It must be based on reliable and objective methodology together with technical and scientific expertise to ensure that there are no doubts about the outcome of the identification process.[2]

The jaws and teeth, in certain cases, are the most well preserved remains of the human body and represent a useful and valuable pieces of information in the process of identification[3]. The three most common methods used for identification are; (1) comparative identification (2) reconstructive identification (3) DNA profiling[4].

The methodology of comparative identification *is* based on comparison of ante mortem (AM) and post-mortem (PM) records including dental charts (odontograms), intra-oral and extra-oral radiographs, clinical photographs, study casts and dental prostheses[5]. Positive identification using this methodology is often achieved with a high degree of reliability and accuracy[4].

The dental pattern (DP) is defined as the combination of distinct codes assigned to specific tooth conditions namely virgin, missing, filling and restored teeth on the entire dentition, or groups of teeth; the resulting pattern is noted and charted in non-radiographic format[6]; this can then be used as a tool in the process of identification. The use of DP has been validated as an excellent mean of individual identification[7,8]. The high diversity of DP has been demonstrated both theoretically, by calculation of possible combinations, and empirically by analysis of large reference datasets. The results suggest that the dental pattern of an individual could often be of sufficient value to be used for purposes of identification and that the diversity of DP could be comparable to the diversity seen in mitochondrial DNA sequences[6,8].

Dental radiographs are often used in the identification process. In some cases they are often preferable to the use of DNA[4,5]. They are relatively simple and quick to acquire and are cheaper than using DNA based techniques. Dental radiographs provide objective evidence that can be used to identify commonalities of anatomical features and dental treatment provided up to a point in time[4,9].

Panoramic radiography (PR) provides a complete view of the teeth, jaws[10] and numerous other features and structures within in a single image[11]. PR represents a reliable source of information for victim identification following incidents of mass disaster, aircraft crash or terrorist attack where there is pressure to identify large numbers of victims as quickly as possible[5].

The diversity of DP in PR has been studied on samples of Koreans[3] and Indians[10,12] respectively but there is a need for more studies in DP to include additional distinct populations[3,10]. DP is closely related to the dental health status and this depends on age and the differences in the dental caries levels (DMFT) between countries[13].

The diversity of dental patterns in panoramic radiography has not been studied in Latin America. The aims of this investigation were to study the dental patterns and determine their diversity in a sample of panoramic radiographs of Peruvian citizens.

MATERIAL AND METHODS

This is a retrospective study using digital PR captured in a private dental radiology centre in Lima, Perú, between 2013-2015. The sample size was determined by

convenience and included all PRs taken between 2013 and 2015 that matched the following: (1) good image quality; (2) patient older than 20 years of age; and (3) presence of at least one tooth. The radiographs of patients with cleft lip and/or palate; orthodontic devices or completely edentulous were excluded.

The DP from any PR was determined by the investigator (IEP) using the codes described by Lee[3] (Table 1). All PRs were acquired on a ProMax® Scara 2 panoramic machine (Planmeca Oy, Helsinki, Finland) and displayed in the ROMEXIS™ software v.3.6.0.R (Planmeca Oy, Helsinki, Finland). To standardize the image quality, the filters Revert-to-original, Clarify and Sharpen-the-image-(3, 1.3) were applied, in this sequence, to the radiographic image.

The DP diversity was calculated for the full dentition-32 teeth, maxilla, mandible, and the sextants upper-right-posterior (UR), upper-anterior (UA), upper-left-posterior (UL), lower-left-posterior (LL), lower-anterior (LA) and lower-right-posterior (LR) respectively.[4] The Simpson´s diversity index was calculated to estimate the DP diversity in the sample (Fig. 1), where P_i represents the frequency of every DP found in the sample.

The DP data was grouped and analysed by using the Statistical Package for Social Sciences (SPSS®) for Windows version 21 (SPSS Inc., Chicago, IL, USA).

The DP of the sample was determined by a single operator. To assess the intra-observer repeatability, the DP of 100 randomly-selected PR was determined in two sessions separated by a period of 2 weeks. Cohen´s kappa coefficient was calculated to be a value of 0.8 which indicates substantial strength of agreement.

RESULTS

The sample size was composed of 900 PR images (450 male and 450 females) taken between 2013-2015 that matched the inclusion criteria mentioned above. The age distribution is described in Table 2.

The most frequent full-dentition DP was all-virgin-teeth (3 patients – 0.3%), all-teeth extracted in the maxilla (17 patients – 1.9%) and all-virgin teeth in the mandible (9 patients – 1%). The most frequent DP in the sextants was all-virgin-teeth and was observed in the UA and LA sextants (308 patients – 34.2% and 651 patients – 72.3% respectively). The results are described in Table 3.

The number of different DPs (the sum of all patterns) and individual DPs were 893 and 887 in the full-dentition, 826 and 800 in the maxilla and 834 – 802 in the mandible. The diversity values calculated for the full-dentition, maxilla, mandible and the UR, UL, LR and LL sextants were over the 99.8% value; the diversity value for the UA and the LA sextants were 87.59% and 47.50% respectively (Tables 4 and 5).

The most commonly observed DPs, the number of DPs and the diversity of the DPs determined for the full dentition of 32 teeth, for the maxilla, for the mandible and for the sextants are described in Tables 3, 4 and 5 respectively.

DISCUSSION

The DP has been studied in research using dental charts obtained from both Spaniards[13] and Brazilians[14]. The DP has also been studied in PR obtained from both Koreans[3] and Indians[10,12]. The overall diversity values reported from both PR and dental charts were 99.9%[10] and 99.7%[12] respectively for Indians, 99.92%[3] for Koreans; 98.2% for Americans (United States)[6]; 99.96% for Spanish[13] and 98-99% for Brazilians.[18-14].

Table 1 – Classified dental patterns seen in orthopantomography (PR) and their corresponding codes	
CODE	**DESCRIPTION**
V (Virgin tooth)	No evidence of dental disease or treatment.
X (Missing tooth)	Extracted or congenital missing tooth.
I (Impacted tooth)	Unerupted or impacted tooth.
D (Defect)	Defect by dental caries, tooth fracture or fallen out fillings.
R (Residual root)	Remained root due to severe dental caries.
T (Root canal treatment)	Root canal filled tooth by endodontic treatment.
F (Filling)	Filled tooth.
P (Prosthesis)	Tooth with crowns.

Table 2 – The age and gender distribution of the sample (n=900)			
AGE	**FEMALE (%)**	**MALE (%)**	**TOTAL (%)**
20 - 29	121 (26.9)	100 (22.2)	221 (24.6)
30 - 39	88 (19.6)	111 (24.7)	199 (22.1)
40 - 49	76 (16.9)	69 (15.3)	145 (16.1)
50 - 59	54 (12)	62 (13.8)	116 (12.9)
60 - 69	61 (13.6)	53 (11.8)	114 (12.7)
70+	50 (11.1)	55 (12.2)	105 (11.7)
TOTAL	450	450	900

Table 3 – The most frequent observed dental patterns observed in the full dentition, maxillae and sextants (n=900)			
AREA	**DP**	**#**	**%**
FULL DENTITION-32 teeth	VVVVVVVVVVVVVVVV VVVVVVVVVVVVVVVV	3	0.3
MAXILLA	XXXXXXXXXXXXXXX	17	1.9
MANDIBLE	VVVVVVVVVVVVVVV	9	1.0
UR	XXXXX	45	5.0
UA	VVVVVV	308	34.2
UL	XXXXX	41	4.6
LL	XXXXX	24	2.7
LA	VVVVVV	651	72.3
LR	VVFFI	30	3.3

Table 4 - Number of different and individual dental patterns in the full dentition, maxillae and sextants observed in the orthopantomography (n=900)		
AREA	**# OF DIFFERENT DP**	**# OF INDIVIDUAL DP**
FULL DENTITION-32 teeth	893	887
MAXILLA	826	800
MANDIBLE	834	802
UR	404	266
UA	339	270
UL	587	444
LL	546	410
LA	142	107
LR	551	413

Table 5 - Diversity of the dental patterns in orthopantomography of the sample (n=900)	
AREA	**DIVERSITY (%)**
FULL DENTITION-32 teeth	99.89
MAXILLA	99.81
MANDIBLE	99.85
UR	98.50
UA	87.59
UL	98.58
LL	98.55
LA	47.50
LR	98.51

This present study is the first in South America to explore DP in PR and is the second study of DP in Latin America; the first study was that of Biazevic et al in 2001[14]. The diversity estimation in the reviewed literature[3,10,12,13,14] was the result of pairwise comparison between each pattern in the studied sample as described by Adams BJ[6]. The present study utilized the Simpson´s Diversity Index which is dependent of the frequency of each pattern itself and not the result of pairwise comparisons between datasets. The diversity value found for Peruvians was 99.89% which confirms the greater diversity of the DP forensic method for personal identification in the studied sample.

The most common DP observed in the full-dentition was 32 virgin teeth for Indians (10.3%[10] and 9.3%[12]) and 28 virgin teeth and four third impacted molars for Koreans (2%[3]), the most common DP found in the full-dentition on Peruvians was 32 virgin-teeth (0.3% - 3 patients). The percentage of individual DP for the full-dentition, maxilla and mandible found in the literature were 79%-57%-66% for Indians[10] and 91%-64%-60% for Koreans[3] respectively; in this present study for Peruvians the results were 99%-89%-89%. The differences may be related to the distinct levels of dental caries in the studied populations (high in Peru, low in the India and moderate in Korea respectively)[13,15] alongside with the decrease in the number of restorative interventions[9] that may reduce the diversity

of the DP. The sample size can be a factor too, especially in the group aged over 50 years because their higher burden of oral disease[16] which may influence the diversification of the patterns.

The high diversity of the DP reported in the literature implies there may be sufficient information to enable personal identification[12]. The number of theoretically possible combinations of the codes utilized can be calculated as C^n, where C is the number of possible characteristics (8 codes) and n is the number of teeth considered (32). The resulting number would be 8^{32} or 79228162514264337593543950336 distinct patterns[6]; this demonstrates that the DP of one individual may be of sufficient value to discriminate that individual.

The PR surpasses dental charting in respect of the amount of available information because it is an exact and objective representation of the patient´s teeth and surrounding bony structures[11,17] whereas dental charting is descriptive and prone to errors, inaccuracies, deliberate falsifications, side interchanges and other mistakes.[11,17,18,19]. During the course of the study it was noted that the available information might improve the description if codes D, R, T, F and P were combined into TD, PD, TR, FT and PT for specific tooth conditions (Fig. 2). The studies of DP in PR did not address this issue perhaps because the samples studied had low prevalence of caries and better access to oral health services whereas the samples studied in this paper came from a country with a high prevalence of caries, worn-out or unfinished treatments and unequal access to oral health services.[15] The additional characteristics would augment the number of theoretically possible combinations from 8^{32} to 12^{32} (the T code is combined with D, R, F and P codes) or 3.4182189187166852111368841966125e+34 possible combinations of the DP in PR. Adams BJ[6,8] states, that there is no need for detailed records to increase the discriminant power of comparative data[14].

$$D = 1 - \sum_{i=1}^{N} (p_i)^2$$

Fig. 1: The Simpson´s index of diversity formula. p_i represents the frequency of every pattern observed in the sample.

The present study would confirm the statement that when dental charting is being used solely as the source of information additional information provided by PR may justify addition to the DP codes. A study designed to compare the diversity of clinical and radiographic DP on a sample could be designed to determine whether significant differences exist when these two sources of information are utilised.

Radiographic imaging techniques have been progressing at a rapid rate over the last decade with improvements in ease of use, image acquisition time and image resolution[20]. The multi-sliced computed tomography (MSCT) and cone beam computed tomography (CBCT) -3D data- is superior to panoramic and intraoral radiography -2D data- because it can be reformatted into a variety of images (radiographic series, panoramic radiography and 3D images)[20,21] without

the need for an additional examination[21] as well as the free manipulation on different axes that allows for a more precise detection and landmarking of reference points[22]. Additionally the generated images can be customized to closely match the anatomic area, the FoV and, most significantly, the angular orientation of the AM images. In situations when AM images are taken at non-standard angles, the possibility to rotate the volume in the three dimensions allows the forensic odontologist to reformat the image to a similar angulation increasing the likelihood of a correct assessment of the anatomic structures and restorations involved[20]. The utility of 3D reformatted images for matching comparison has been reported by Murphy et al. (OPG compared to reformatted OPG)[21] and Trochesset et al. (periapical radiography compared to reformatted intraoral-like radiography)[20]. Both studies found positive results with respect to the matching comparison. A DP can be determined in 3D reformatted images and then contrasted with a PR but this stage would not be necessary if a matching comparison of the AM and PM 3D images could be performed.

Uniqueness can be interpreted as meaning the existence of only one of its kind (person, thing or trait)[23] and, as a concept, implies that there will never be a repetition of what is being observed in any person, thing or trait[24]. It is recognised that this hypothesis cannot be proven in *sensu stricto*[23,24] because it is physically impossible to measure the number of indeterminates[23] that determine the concept of uniqueness on a global basis. In the human dentition, the concept of uniqueness is described as the combination of morphological and positional information obtained from each tooth in respect of comparison to every other dentition in the world[23,22].

Fig. 2: Cropped PR showing examples of codes proposed for specific tooth conditions (in parentheses): 21, 22, 23, and 24 (TR); 34 (PT); 43 (TD); 44 (FT); 45 (PD).

The DP methodology is based on a limited number of possible combinations (upper limit of millions). The possible combinations can be increased by addition or combination of codes for specific teeth conditions. The possibility of repetitions indicate that a DP cannot be unique irrespective of the source of information (dental charts, PR, 3D data or dental photography) but that the diversity of DP's would allow further refinement to identify those individuals who could possibly be evaluated by other methodology. The other methodology could include, for example, CBCT and/or MSCT. Using this

strategy could improve the probability of a match[25].

This paper has addressed the advantages of using DP methodology. These advantages include simplicity and the higher diversity as reported in empirical and descriptive studies currently available in the literature.

Against this background the DP is proposed as a useful technique in the identification process.

It must be noted that, in some cases, the eventual outcome of an identification process will be inconclusive. Nonetheless there is a threshold, or series of thresholds, that makes the likelihood of identity proportionately higher or lower[24]. Against this background every source of additional information is paramount.

CONCLUSIONS

- The diversity of DPs has been demonstrated in a sample from Peruvian citizens
- The overall diversity value for the full-dentition of DPs of a sample of Peruvian adults was 99.89% which is similar to that from other countries as published in the literature.
- The differences for the individual DPs of the full-dentition, maxilla and mandible of the studied population groups may be due to the distinct dental caries levels that exist between various countries.
- A combination of codes for specific tooth conditions is proposed as a way to improve the description of the dental patterns in panoramic radiography.

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