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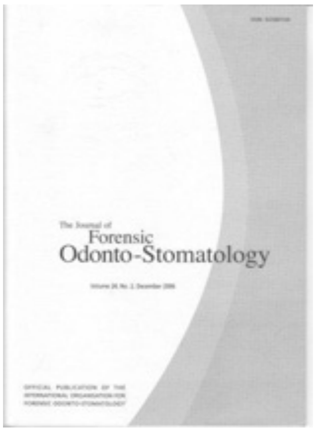

THE JOURNAL OF FORENSIC ODONTO-STOMATOLOGY

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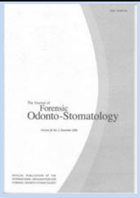

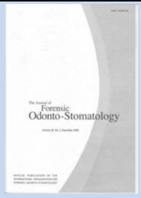

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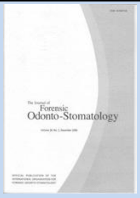

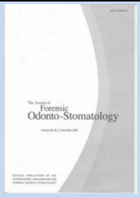

JOURNAL of FORENSIC ODONTO-STOMATOLOGY

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SECTION IDENTIFICATION

The Use of Incinerated Pig Head in Dental Identification Simulation

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The authors declare that they have no conflict of interest.

ABSTRACT

Purpose: The aim of this exercise was to simulate a disaster victim identification scenario to allow training in documentation of postmortem incinerated remains and reconciliation of dental data.

Method: Varying number of restorations were placed in ten pig heads. The teeth and restorations were charted, with the restorations radiographed and documented, creating an ante-mortem data set. The following day the heads were cremated. Following cooling and recording they were transported for a post-mortem examination by trained specialist odontologists who were not involved in the initial antemortem phase. Recordings included the charting of teeth, restorations, lost teeth, and radiographs to simulate a post-mortem examination. A reconciliation of postmortem to antemortem information was attempted.

Results: There was an unacceptable amount of error in the postmortem examination of the heads. The errors related mainly to avulsed teeth and incorrect opinion of which charted surfaces the restorations were placed upon. Also noted were a considerable number of root fractures occurring beneath the crestal bone. This observation does not mimic the evidence observed in human incinerated teeth where the crowns tend to fracture off the roots at the dentin-enamel junction.

Conclusion: The use of incinerated pig (Sus Scrofa) heads is not an ideal model for forensic odontology training in disaster victim identification. Differences in both anatomy and behavior following exposure to heat were shown to hamper documentation and subsequent comparison to antemortem data.

***KEYWORDS*: **Forensic odontology, identification, incineration, pig heads, stabilization.

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INTRODUCTION

The identification of deceased victims is required for legal and ethical reasons. [1] The process of identification in a severe fire event may be extremely difficult and prolonged due to damage or destruction of physical evidence such as clothing, documents, tattoos, fingerprints, and hair; [2] furthermore DNA may be unobtainable [3] As the dental structures are the most resilient structures of the body [4, 5] they are commonly utilized as the identifying method of choice in severely incinerated cases. However, the loss of water and organic component causes shrinkage and cracking of the teeth and supporting bone [6, 7] consequently any minor force can fracture the brittle teeth and bones or cause teeth to be dislodged. This causes disruption of bony features and loss of the anatomical location of teeth. [8-10] This loss of postmortem evidence leads to examination problems with regards to comparison of antemortem and postmortem data with subsequent delays to the reconciliation (formal identification) phase of the investigation. [11] These delays create frustration and anger for relatives and friends of the victims as sometimes months may pass before the authorities have sufficient information to release the remains.[12] Therefore it is vital to maximize the postmortem information by creating an appropriate pre-disaster protocol and quality control, with the enforcement of that protocol through training and maintaining Standard Operating Procedures. [13] Much of the success of any identification operation can be attributed to pre-planning, a sound response plan and training. [14-16] Areas of training specifically related to incinerated remains include the use of stabilization sprays of remains before movement, wrapping and protection of the heads before transportation, handling, documentation and radiography.

The aim of this exercise was to simulate a disaster victim identification scenario to allow training in documentation of postmortem incinerated remains and reconciliation of dental data. For this purpose pig (*Sus Scrofa*) heads were considered for a training exercise involving incinerated tissues. They are readily available, inexpensive and similar in size to human heads. As they are an omnivore rather than herbivore, the enamel and dentine from swine and human teeth share structural similarities, [17] although there is a greater stiffness and high fracture resistance of human cusps. [18] Figure 1 displays the anterior teeth of a juvenile *Sus Scrofa*.

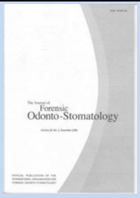
A previous study has shown that the oral maxillofacial region of miniature pigs is similar to that of humans in anatomy, development, physiology, and disease occurrence. [19] As the heads were to be incinerated, previous research has noted that the burning of lean pig's tissue is comparable to burning of human remains. [20]

MATERIALS AND METHODS

Animal ethical approval was granted by the University of Adelaide for the study to take place, using pig heads sourced from a local abattoir.

Ten heads were transported from the abattoir to a non-clinical laboratory. Utilizing disposable hand pieces and burs, varying numbers of restorations were placed in each head. The teeth and restorations were charted, with the restorations radiographed and documented, creating an antemortem data set.

The following day the heads were placed in an animal crematorium furnace. Within the furnace, each head was placed on a separate ceramic tile and cremated for 4 hours. Following cooling, the tiles were taken carefully out of the furnace. Each tile



(with the head upon them) was carefully placed in a separate clear plastic bag and then into a body bag with bubble wrap. The body bag was transported for a trip of approximately 50 miles for a postmortem examination by trained specialist odontologists who were not involved in the initial antemortem phase. Recordings included the charting of teeth, restorations, lost teeth, and radiographs to simulate postmortem examination. Anatomical bone structure damage and the subjective ease of examination and radiograph taking were noted. Results were tabulated to correspond with the antemortem information for comparison and a reconciliation of postmortem to antemortem information was attempted.

Fig. 1: Image of anterior teeth of juvenile *Sus Scrofa* demonstrating the anatomical circular form of the lower incisors.

RESULTS

The results of the postmortem condition of the teeth are shown in Table 1 with damage sustained due to the incineration and travelling processes.

Table 1. The results of the postmortem condition of the teeth

Pig head no.	Lost in transport	Fractured crowns	Fractured roots	Tooth displaced
1	0	0	3	1
2	0	2	4	0
3	0	3	4	1
4	2	2	3	0
5	0	1	3	1
6	0	5	3	1
7	0	3	2	0
8	0	0	7	0
9	0	3	1	1
10	0	3	6	0

All the restorations remained in place. However, despite care having been taken over the transportation process, two teeth (both from case 4) were lost between incineration and examination. Eight of the heads displayed at least one fractured crown; all had fractured roots and loosening resulting in displacement from their sockets of teeth in 5 of the 10 heads. This proved to be a problem with regards to the anterior teeth as their circular morphology meant they could not be correctly orientated when placed back in the jaw. Table 2 tabulates the postmortem examination findings that could affect the reconciliation processes.

Table 2. Tabulation of postmortem examination findings

Pig head no.	Incorrect nomenclature	Missed restorations
1	0	4
2	2	1
3	0	0
4	1	2
5	3	1
6	2	0
7	1	1
8	0	0
9	3	1
10	2	1

DISCUSSION

Several difficulties were noted during this study. During the placement of the restorations in the antemortem phase rigor mortis occurred quickly. The size of the masseter and temporalis muscles of *Sus Scrofa* mean maxilla and mandible are soon difficult to separate. To overcome this it is suggested that soon after the slaughter of the animal the jaws are wedged apart to maintain easy access for the placement of restorations and the wedge subsequently removed to allow closure of the jaws before incineration. There were also difficulties in radiographing the teeth, due to a mismatch between the width of the pigs' jaws and the width of the digital sensor, resulting in elongation of the digital images.

In retrospect it was noted that the incineration had not been ideal. There had been uneven incineration of the heads due to their positioning relative to the to the heat inlet portals and the ceramic tiles on which the heads had been placed for easy extraction fractured due to heat. These issues could be resolved by better placement of the heads and use of metal trays.

Of note was a considerable number of root fractures occurring beneath the crestal bone with an example seen in Fig. 2.

Fig. 2: Postmortem radiograph demonstrating root fractures beneath the crestal bone.

This observation does not mimic the position of fractures observed in human incinerated teeth where the crowns tend to fracture off the roots at the dentin-enamel junction, an example of which is shown in Fig. 3.

There was a significant error rate in the postmortem examination of the heads. The errors related mainly to dislodged teeth and subsequent incorrect opinion of which charted surfaces the restorations were placed upon. This can be explained by the fact that the pig's lower anterior teeth have a circular morphology and it is difficult to orientate the displaced teeth correctly for charting, irradiating or replacing them into their sockets correctly. An example can be seen in Fig. 4 to Fig. 6.

Fig. 4 is the antemortem radiograph of the lower anterior teeth and of note is that the lower *left* lateral has two restorations with one of them clearly positioned on the distal surface. Fig. 5 has the postmortem radiograph of the 42 to 31 teeth showing correct orientation, however Fig. 6 (the radiographic image of tooth 32 incorrectly orientated) displays a mesially placed restoration but no distal restoration.

This lack of restoration on the distal surface would exclude a match. Due to the fractured crowns and teeth displaced, seven out of the total ten heads had at least one nomenclature discrepancy. These errors would be unacceptable in a real-life situation, and would adversely affect the

Fig. 3: An example of incineration induced fractures at or above the crestal bone height in a human.

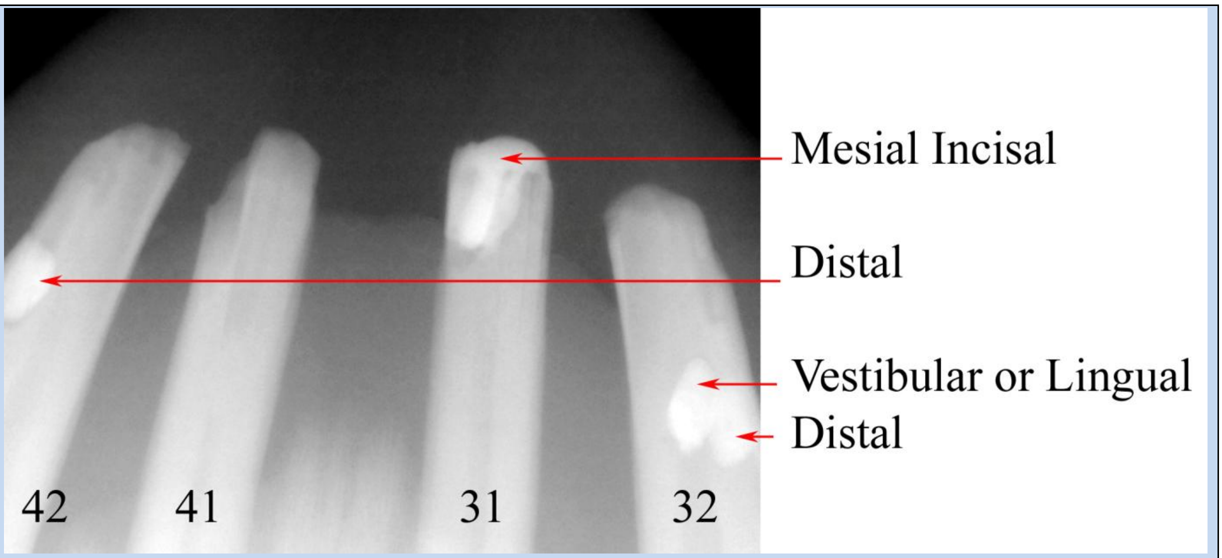


Fig. 4: Antemortem radiograph of 31, 32, 41 and 42 teeth showing four restorations including a distal restoration on the 42 tooth.

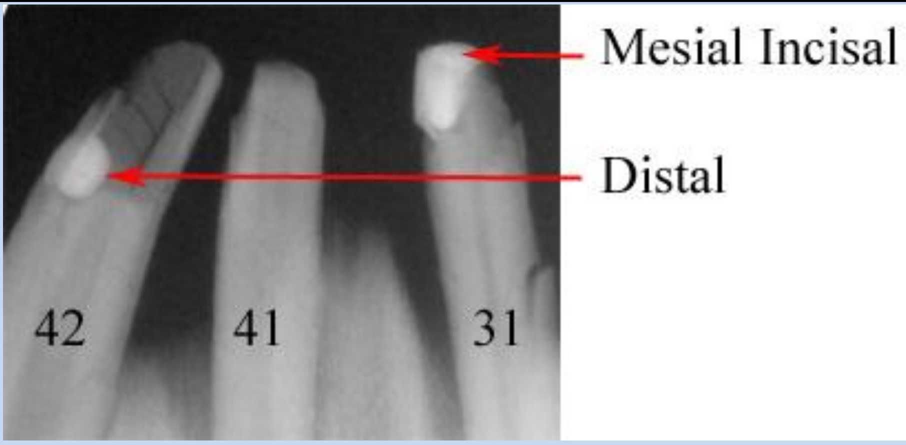


Fig. 5: Postmortem radiographs of the same area as Fig. 5 with the 31, 41 and 42 teeth correctly orientated.

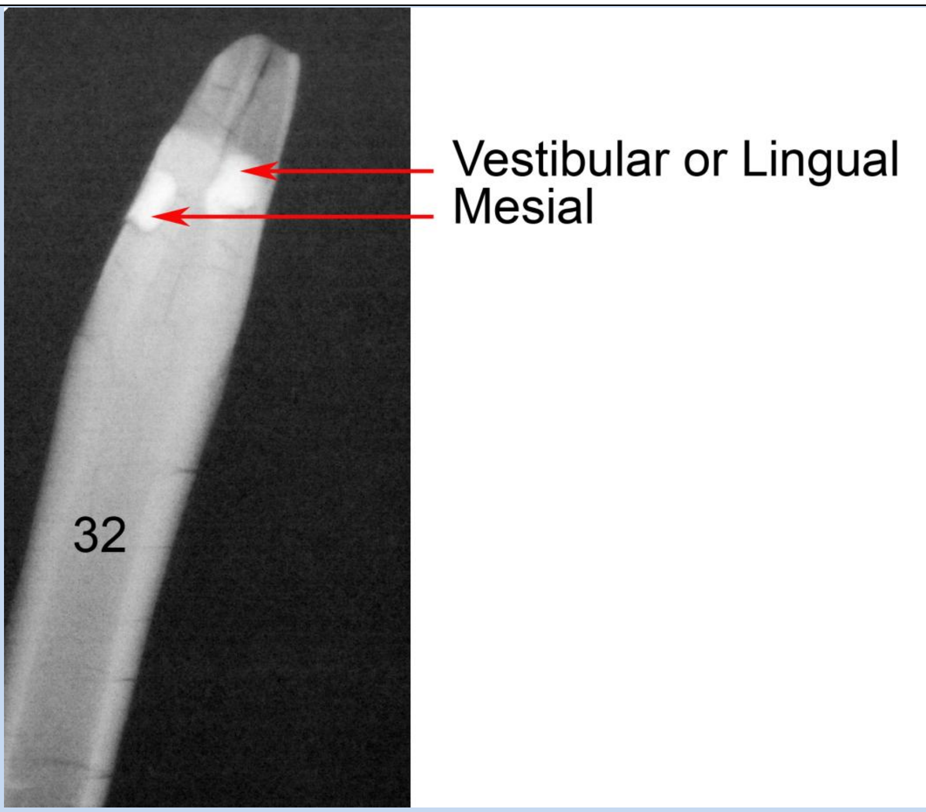


Fig. 6: Postmortem radiograph of the 32 tooth incorrectly orientated suggesting a mesially placed restoration.

reconciliation process. As a consequence of these observations it was decide not to continue to utilize incinerated pig heads as a model for the forensic odontological training.

CONCLUSION

Incinerated pig (*Sus Scrofa*) heads is not an ideal model for forensic odontology training in disaster victim identification. Differences in both anatomy and behavior following exposure to heat were shown to hamper documentation and subsequent comparison to antemortem data.

ACKNOWLEDGEMENTS

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REFERENCES

1. Cordner SM, Woodford N, Bassed R. Forensic aspects of the 2009 Victorian Bushfires Disaster. *Forensic Sci Int.* 2011;205:2-7.
2. Holden JL, Clement JG, Phakey PP. Age and temperature related changes to the ultrastructure and composition of human bone mineral. *J Bone Miner Res.* 1995;10:1400-9.
3. Imaizumi K, Taniguchi K, Ogawa y. DNA survival and physical and histological properties of heat-induced alterations in burnt bones. *Int J Legal Med*. 2014;128:439-46.
4. Woisetschläger M, Lussi A, Persson A, Jackowski C. Fire victim identification by post-mortem dental CT: radiologic evaluation of restorative materials after exposure to high temperatures. *Eur J Radiol.* 2011;80:432-40.
5. White TD. Human Osteology. San Diego: Academic press; 1991.
6. Thompson TJ. Recent advances in the study of burned bone and their implications for forensic anthropology. *Forensic Sci Int*. 2004;146 Suppl:S203-5.
7. Reichs KJ. Forensic osteology : advances in the identification of human remains 2nd ed. Springfield: Charles C. Thomas; 1998.
8. Griffiths CJ, Bellamy GD. Protection and radiography of heat affected teeth. *Forensic Sci Int.* 1993;60:57-60.
9. Cardoza AR. Dental forensic identification in the 2003 Cedar Fire. *J Calif Dent Assoc.* 2004;32:689-93.
10. Park DK, Park KH, Ko JS, Kim YS, Chung NE, Ahn YW, et al. The role of forensic anthropology in the examination of the Daegu subway disaster (2003, Korea). *J Forensic Sci.* 2009;54:513-8.
11. Hill AJ, Lain R, Hewson I. Preservation of dental evidence following exposure to high temperatures. *Forensic Sci Int.* 2011 Feb 25;205:40-3.
12. Coroner eases process to id fire victims. The Australian; 2009. Available from: http://www.theage.com.au/national/coroner-eases-process-to-id-fire-victims-20090305-8q2v.html#ixzz1qqaXd0Ju [cited 12 May 2012].
13. Lake AW, James H, Berketa JW. Disaster victim identification: quality management from an odontology perspective. *Forensic Sci Med Pathol.* 2012;8:157-63.
14. De Winne J. Preparing for major incidents. *Forensic Sci Int.* 2006; 159S:S9-S11.
15. Lain R, Taylor J, Croker S, Craig P, Graham J. Comparative dental anatomy in Disaster Victim Identification: Lessons from the 2009 Victorian Bushfires. *Forensic Sci Int.* 2011;205:36-9.
16. Pretty IA, Webb DA, Sweet D. The design and assessment of mock mass disasters for dental personnel. *J Forensic Sci.* 2001:46, 74-9.
17. Lopes FM, Markarian RA, Sendyk CL, Duarte CP, Arana-Chavez VE. Swine teeth as potential substitutes for in vitro studies in tooth adhesion: a SEM observation. *Arch Oral Biol.* 2006;51:548-51.
18. Popowics TE, Rensberger JM, Herring SW. Enamel microstructure and microstrain in the fracture of human and pig molar cusps. *Archives Oral Biology.* 2004;49:595-605.
19. Owsley DW. Identification of the fragmentary, burnt remains of two U.S. journalists seven years after their disappearance in Guatemala. *J Forensic Sci.* 1993;38:1372-82.
20. DeHaan JD, Campbell SJ, Nurbakhsh S. Combustion of animal fat and its implications for the consumption of human bodies in fires. *Sci Justice.* 1999;39:27-38.

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SECTION IDENTIFICATION

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	XXXXXXXXXXXXXXXX	17	1.9
MANDIBLE	VVVVVVVVVVVVVVVV	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.

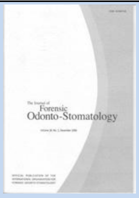
It must be noted that, in some cases, the eventual outcome of an identification process will be inconclusive. Nonetheless there is a threshold, or series of thresholds, that makes the likelihood of identity proportionately higher or lower[24]. Against this background every source of additional information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

REFERENCES

1. Happonen RP, Laaksonen H, Wallin A, Tammisalo T, Stimson PG. *Use of orthopantomographs in forensic identification*. *Am J Forensic Med Pathol* 1991;12:59-63.
2. Da Silva RF, Nunes FG, de Faria Neto JC, Costa Rege IC, Daruge Junior E. *Forensic importance of panoramic radiographs for human identification*. *RGO, Rev Gaúch Odontol* 2012;60:527-31.
3. Lee SS, Choi JH, Yoon CL, Kim CY, Shin KJ. *The diversity of dental patterns in the orthopantomography and its significance in human identification*. *J Forensic Sci* 2004;49:784-6.
4. Shahin KA, Chatra L, Shenai P. *Dental and craniofacial imaging in forensics*. *J Forensic Radiol and Imaging* 2013;1:56-62.
5. Kumar N, Sreenivasan V, Patil V, Vashishth S. *Panoramic imaging as a tool of identification in forensic odontology*. *Indian J Forensic Odontol* 2013;6:51-8.
6. Adams BJ. *The diversity of adult dental patterns in the United States and the implications for personal identification*. *J Forensic Sci* 2003;48:497-503.
7. Singh S, Bhargava D, Deshpande A. *Dental orthopantomograms biometrics system for human identification*. *J Forensic Leg Med* 2013;20:399-401.
8. Adams BJ. *Establishing personal identification based on specific patterns of missing, filled and unrestored teeth*. *J Forensic Sci* 2003;48: 487-96.
9. Wood RE. *Forensic aspects of maxillofacial radiology*. *Forensic Sci Int* 2006;159:S47-55.
10. Bhateja S, Arora G, Katote R. *Evaluation of adult dental patterns on orthopantomograms and its implication for personal identification: A retrospective observational study*. *J Forensic Dent Sci* 2015;7:14-7.
11. Du Chesne A, Benthaus S, Teige K, Brinkmann B. *Post–mortem orthopantomography – an aid in screening for identification purposes*. *Int J Legal Med* 2000;113:63-9.
12. Kumar A, Ghosh S, Logani A. *Occurrence of diversity in DP and their role in identification in Indian population: An orthopantomograms based pilot study*. *J Forensic Dent Sci* 2014;6:42-5.
13. Martin-de-las-Heras S, Valenzuela A, Luna-J-de D, Bravo M. *The utility of dental patterns in forensic dentistry*. *Forensic Sci Int* 2010;195:166e1.-5,



14. Biazevic MG, de Almeida NH, Crosato E, Michel-Crosato E. *Diversity of dental patterns: Application on different ages using the Brazilian National Oral Health Survey*. *Forensic Sci Int* 2001;207:240.e1-240.e9.
15. Petersen PE. *The world health report 2003: continuous improvement of oral health in the 21st century-the approach of the WHO Global Oral Health Programme*. *Community Dent Oral Epidemiol* 2003;31Suppl1:3-23.
16. Pitts N, Amaechi B, Niederman R, Acevedo A-M, Vianna R, Ganss C, et al. *Global oral health inequalities: dental caries task group – research agenda*. *Adv Dent Res* 2011;23:211-20.
17. Forrest AS. *Collection and recording of radiological information for forensic purposes. Aust Dent J* 2012;57:24-32.
18. Lorkiewicz-Muszyńska D1, Przystańska A, Glapiński M, Kociemba W, Żaba C. *Difficulties in personal identification caused by unreliable dental records. J Forensic Leg Med* 2013; 20:1135-38.
19. Waleed P, Baba F, Alsulami S, Tarakji B. *Importance of dental records in forensic dental identification. Acta Inform Med* 2015;23:49-52.
20. Trochesset DA, Serchuk RB, Colosi DC. *Generation of intra-oral-like images from cone beam computed tomography volumes for dental forensic image comparison. J Forensic Sci* 2014;59:510-3.
21. Murphy M, Drage N, Carabott R, Adams C. *Accuracy and reliability of cone beam computed tomography of the jaws for comparative forensic identification: a preliminary study. J Forensic Sci* 2012;57:964-8.
22. Franco A, Willems G, Souza PH, Bekkering GE, Thevissen P. *The uniqueness of the human dentition as forensic evidence: a systematic review on the technological methodology. Int J Legal Med* 2014;Nov 15[Epub ahead of print]. DOI:10.1007/s00414-014-1109-7.
23. Jayaprakash PT. *Practical relevance of pattern uniqueness in forensic science. Forensic Sci Int* 2013;231:403.e1-16.
24. Page M, Taylor J, Blenkin M. *Uniqueness in the forensic identification sciences-Fact or fiction? Forensic Sci Int* 2011;206:12-8.
25. Johansen RJ, Bowers M. *Positive dental identification using tooth anatomy and digital superimposition. J Forensic Sci* 2013;58:534-6.

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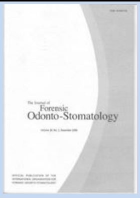

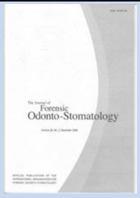

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SECTION ANTHROPOLOGY AND ARCHEOLOGY

Prediction of Anthropometric Measurements from Tooth Length – A Dravidian Study

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The authors declare that they have no conflict of interest.

ABSTRACT

***Background:** Anthropometric measurement is essential for identification of both victims and suspects. Often, this data is not readily available in a crime scene situation. The availability of one data set should help in predicting the other.*

This study was hypothesised on the basis of a correlation and geometry between the tooth length and various body measurements.

***Aim and objective:** To correlate face, palm, foot and stature measurements with tooth length. To derive a regression formula to estimate the various measurements from tooth length.*

***Materials and methods:** The present study was conducted on Dravidian dental students in the age group 18 - 25 with a sample size of 372. All of the dental and physical parameters were measured using standard anthropometric equipments and techniques.*

***Results:** The data was analysed using SPSS software and the methods used for statistical analysis were linear regression analysis and Pearson correlation. The parameters (incisor height (IH), face height (FH), palm length (PL), foot length (FL) and stature (S) showed nil to mild correlation ($R = 0.2 \leq 0.4$) except for palm length (PL) and foot length (FL). ($R>0.6$).*

***Conclusion:** It is concluded that odontometric data is not a reliable source for estimating the face height (FH), palm length (PL), foot length (FL) and stature (S).*

***KEYWORDS*:** tooth length, face length, palm length, foot length, height, Dravidians

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INTRODUCTION

Anthropometry comprises a series of systematized measuring techniques that expresses quantitatively the dimensions of the human body including skeletonised remains. It is a highly objective and reliable technique that can be used for the identification of individuals linked to a crime scene. Somatometry, cephalometry, craniometry and osteometry are the different tools used in anthropometry and these tools been proved to be valid in the identification of human remains[1]. Anthropometric difference varies between races and is influenced by national social and economic conditions[2]. The major races of the world population are broadly categorized as Caucasian, Mongolian, Negroid or Austroloid[3]. Indians belong to a Caucasian sub-group termed Indo-Dravidian. India is a diverse country with varied races including Aryans, Dravidians and Mongolians[4,5].

Knowledge relating to variation in the dimensions of the human body is important in not only in medico-legal identification but is also helpful in plastic surgery, prosthetic replacement and cancer research[6]. Teeth are the least destructible component of the body and can survive extreme environmental insult. In some circumstances dental anthropometric data can be used when other forensic data are not available; measurements of erupted teeth are comparable with other skeletal dimensions[7].

Despite numerous published anthropometric studies very few studies addressed the correlation of dental and physical anthropometric measurements of Dravidians. Against this background the hypothesis of this study is; "There is a correlation and geometry between the tooth length and various body measurements[6]. It is established that the skin, the hair, head form, face form, the nose, the eyes, the stature and dentition are distinguishing and unique features for each race[8]. This study uses physical and dental anthropometric tools to compare data and to derive a regressive equation for the Dravidian population.

MATERIAL AND METHODS

This study was a cross-sectional study including 372 subjects aged between 19 to 23 years. 83 subjects were male & 289 subjects were female. All of the samples were obtained from Dravidian dental students with single ancestral origin. Ethical clearance was obtained from the institution. The details of the study were explained and written informed consent was obtained from each student agreeing to participate in the study. Participants with any kind of deformity, either congenital or acquired, were excluded. A pre-requisite for inclusion in the study was good periodontal health. The five parameters included in the study were stature (S), palm length (PL), foot length (FL), face height (FH) and incisor height (IH).

Stature (S) was measured in a standing position to the vertex in Frankfurt plane by using an anthropometric rod. Total facial height (FH) was noted as the distance between the nasion and the gnathion and measured using a vernier caliper. For foot length (FL) and palm length (PL) the foot and palm were moistened with surgical spirit and placed on a large ink pad making sure that the palm and foot were fully extended. The left foot and palm were taken to maintain uniformity.

The palm length (PL) was measured as the distance between the interstyloid line and tip of the middle finger which was recorded by using an ink pad.

The foot length (FL) was recorded as the maximum length between most prominent posterior part of the heel and tip of second toe. A divider was used to measure the length and the findings were recorded in centimetres.

The incisor height (IH) was measured with a divider as the maximum distance between the marginal gingiva and incisal edge. The results were statistically analysed and correlated with multiple linear regression using the method of Pearson.

RESULTS

The odontometric parameter incisor height (IH) was compared to all other parameters including facial height (FH), palm length (PL), foot length (FL) and stature (S). Firstly IH and FH were compared and correlated (Fig. 1, Table 1& 5).

A variation of 0.069 obtained. The regression equation was found to be FH = 14.176 + 2.264 x IH. IH and PL were compared and correlated (Fig. 2, Table 2& 5). A mild variation of 0.023 was obtained; the regression equation was found to be PL = 15.699 + 1.379 x IH.

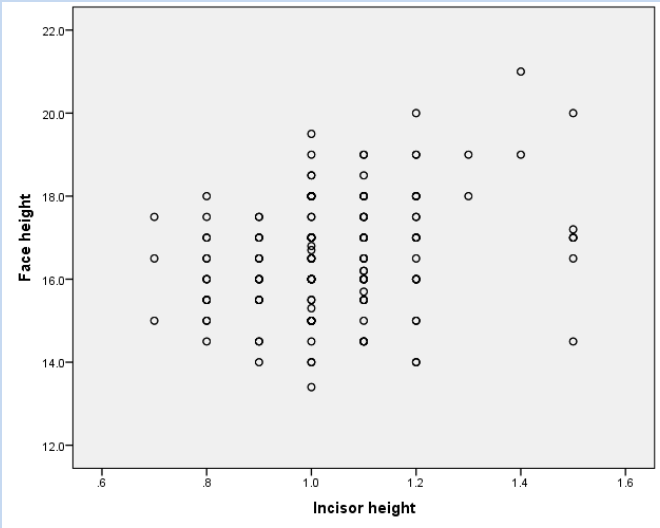

Fig.1: Correlation between incisor height and face height (measurement in mm)

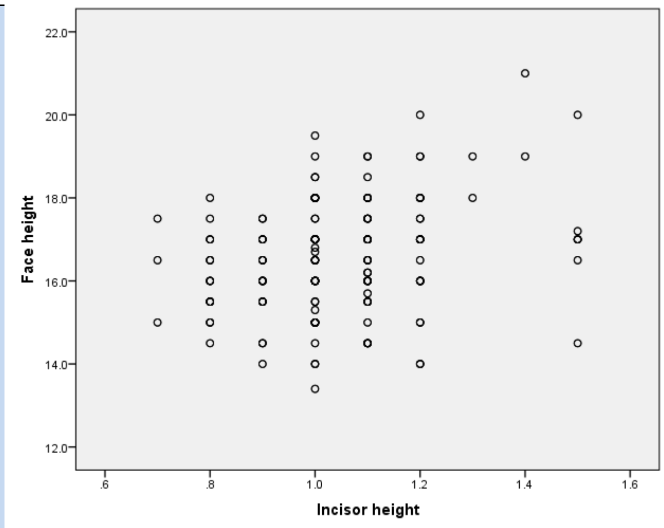

Fig.2: Correlation between incisor height and palm length (measurement in mm)

Fig. 3, shows the comparison and correlation between the IH and FL with a variation of 0.034; the regression equation was found to be being FL = 19.640 +

3.092 x IH. This demonstrates that there is only mild correlation between IH and FL.

Fig. 4, reveals the comparative variable for IH and S to be 0.061. This demonstrates that there is only a mild correlation between the parameters. The regression equation was found to be S = 141.153 + 19.828 x IH.

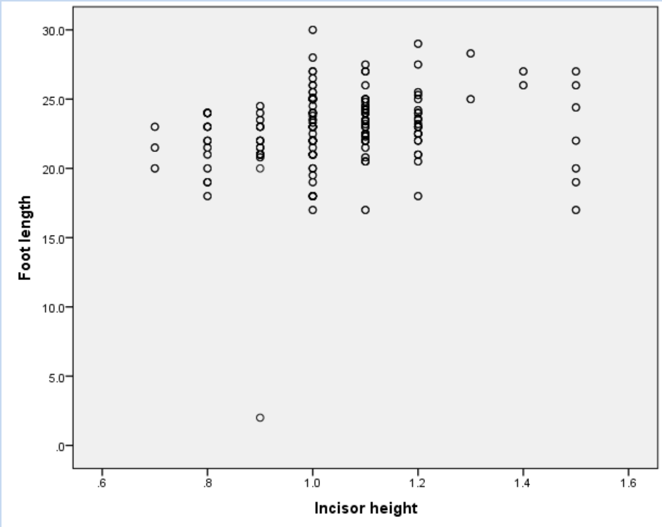

Fig.3: Correlation between incisor height and foot length (measurement in mm)

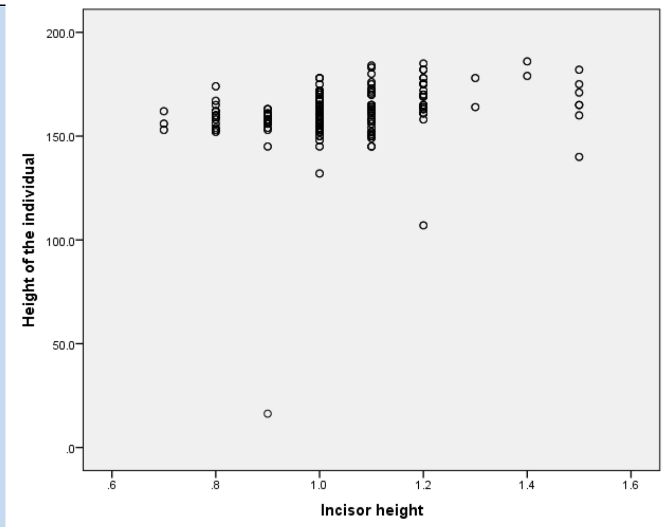

Fig.4: Correlation between incisor height and foot length (measurement in mm)

Table 1: Linear regression equation for various parameters from incisor height (measurement in mm)

Parameter	Unstandardized Coefficients		Standardized Coefficients	t-Value	P-Value	95.0% Confidence Interval for B		Regression Equation
	B	Std. Error				Lower Bound	Upper Bound	
Constant	14.176	.454						Face height = 14.176 + 2.264 × Incisor height
Incisor Height	2.264	.43 1	.263	5.251	<0.001	1.416	3.112	
(Constant)	15.699	.492						Palm length = 15.699 + 1.379 × Incisor height
Incisor height	1.379	.467	.152	2.955	0.003	.461	2.297	
(Constant)	15.699	.492						Foot length = 19.640 + 3.092 × Incisor height
Incisor height	3.092	.854	.185	3.621	<0.001	1.413	4.771	
(Constant)	141.153	4.261						Height = 141.153 + 19.828 × Incisor height
Incisor height	19.828	4.045	.247	4.902	<0.001	11.874	27.783	

Table 2: Correlation between all the parameters of the study

		Face height	Palm height	Foot length	Height of the individual
Incisor height	Correlation	0.263	0.152	0.185	0.247
	P-Value	<0.001	0.003	<0.001	<0.001
	N	372	369	370	372
Face height	Correlation		0.451	0.371	0.342
	P-Value		<0.001	<0.001	<0.001
	N		369	370	372
Palm height	Correlation			0.623	0.416
	P-Value			<0.001	<0.001
	N			369	369
Foot length	Correlation				0.411
	P-Value				<0.001
	N				370

DISCUSSION

It is generally accepted that Crime Scene Investigators consider dental records to be of reliable evidential value. It has been stated that the dentition and jaw pattern of an individual are unique and that tooth measurements can used to assist in the identification of a suspect or victim. Anthropometry can play an important role in catastrophic events such as fire where the teeth and bones may be discovered that represent the sole remnants of the victim [5, 6]. In most cases medico-legal investigators have access to some odontometric data and, in some cases, such as described above, this may prove to be the only source of relevant data for purposes of identification [7].

It has been postulated that stature can influence tooth height since it has an impact on face height. Human body parts have been shown to correlate with stature and biologic measurements are unique for the species Homo sapiens. A number of factors including age, race, gender and nutritional status affect human development and growth. These factors can differ, sometimes drastically, between different races [8]. There are numerous studies published in the literature designed to estimate stature from arm, leg, foot and finger measurements. One conclusion from the studies was that geometry existed between the stature and the extremities, the head, the trunk and the vertebral column [(6)]. Currently a lacunae of similar studies exists in Dravidian populations. The present study was formulated to predict the palm length (PL), foot length FL), facial height (FH) and stature (S) from incisor height and to correlate the parameters.

In the present study on correlating IH with FH, the variation factor was 0.069 indicating a nil correlation between incisor height and face height The regression equation was found to be FH = 14.176 + 2.264 x IH (Graph 1,Table 1). Taller people do possess long teeth that contribute to an increase in face height. However the correlation between face and tooth dimension remains controversial. In a study by Arthur et al the ratio of incisor length and facial height was found to be 1:16 [(9)]. The results of the present study are not in accordance with this figure.

Comparison of IH and PL revealed only a mild variation (r = 0.023) with a regression equation of PL = 15.699 + 1.379 x IH (Graph 2, Table 2). Kamel et al (1990) concluded that palm length alone can attribute in estimating stature and not the palm width [(10)]. Further research is needed to establish whether IH and PL can be correlated.

Correlation of IH and FL resulted in a variation factor of 0.034; the regression equation was found to be FL = 19.640 + 3.092 x IH (Graph 3,). This demonstrates only mild correlation between the IH and FL. Previous studies have demonstrated positive correlation between height and long bones which is in accordance with an African research work done in children [(11)]

In the present study no association was demonstrated between IH and S (r=0.061) meaning only mild correlation between the parameters. The regression equation was found to be S = 141.153 + 19.828 x IH (Graph 4, Table 4&4A). This result is in agreement with two previous studies, one based on individuals from Sri Lanka [(12)] and the other on individuals of Caucasian race [(13)]. Ozaki et al [(14)] reported that there exists a possible correlation between tooth length and stature. However the study of Ozaki [(14)] was based on total tooth length including the lengths of both the crown and the root. In their study of an Afro-American population Henderson and Corruccini infer that only mesio-distal and bucco-lingual tooth parameters can predict stature height [(15)]

In the present study comparison of the anthropometric parameters demonstrated strong correlation between FL and PL of 0.623. This was statistically significant with a P value less than <0.001. This suggests that the PL can be derived from FL and vice versa. Although a significant P value was obtained when comparing the other parameters, the correlation was found to vary from nil to moderate and this can be attributed to the large sample size. This fact is contradictory to the previous research results by Kamel A et al [(10)], Krishnan et al [(4)] and Khanapurkar et al [(16)]. All of these studies conclude that the hand and feet parameters are reliable sources to derive stature estimation. The study of Stanley et al [(17)] correlated tooth size with body size and included several different races and species. The findings of this study yielded nil correlation and these findings are in accord with the findings of the present study.

Further research is proposed in an attempt to explore the current finding of minimal correlation between the anthropometric parameters. The present study relied on measurement of the clinical height of the incisor tooth. Future studies will investigate the anatomical height of the incisor facilitated by the use of radiographs.

CONCLUSION

It was previously assumed that from incisal height (IH) other parameters including facial height (FH), palm length (PL), foot length (FL) and stature (S) could be

determined. However the present study demonstrated minimal correlation between the anthropometric parameters. It is suggested that incisor length is not validated in predicting the other biological measurements in the Dravidian population. It is likely that the palm length (PL) can be estimated from the foot length (FL).
Against this background the authors of this study suggest that incisor height (IH) is not a reliable data source to predict/derive other anthropometric parameters. These parameters include facial height (FH), palm length (PL), foot length (FL) and stature (S). Odontometry cannot be used to predict facial height (FH), palm length (PL), foot length (FL) and stature (S).

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REFERENCES

1. M. K. Bhasin. Morphology to Molecular Anthropology: Castes and Tribes of India Int J Hum Genet 2009; 9(3-4): 145-230
2. Pradeep Bokariya, Bharat Sontakke, JE Waghmare, Aaditya Tarnekar, BH Tirpude, MR Shende. The Anthropometric Measurements of Tibia J Indian Acad ForensicMed.2012; 34(4)322-324
3. MEJ Lean, TS Han, H Bush, AS Anderson, H Bradby and R Williams. Ethnic differences in anthropometric and lifestyle measures related to coronary heart disease risk between South Asian, Italian and general-population British women living in the west of Scotland. International Journal of Obesity (2001) 25, 1800–1805
4. K Krishan. *Anthropometry in Forensic Medicine and Forensic Science-'Forensic Anthropometry*. The Internet Journal of Forensic Science. 2006;2 (1):1-3
5. David Van Sickle, Sheryl Magzamen, John Mullay. Understanding socioeconomic and racial differences in adult lung function. American journal of Respiratory and Critical care medicine.2011;184(5)521-527
6. Dr. Vijaykumar B. Jatti, Dr. Nagesh C. Kuppast, Dr. Shahina, Dr. Dileep Kumar , Dr. Shradha Iddalgave and Dr Vasudeva Murthy.C. Estimation of Height of the Person from Foot Length in Davangere District International Journal of Plant, Animal and Environmental Sciences. 2013;13(4):147-152
7. A Pretty, D Sweet. Forensic dentistry: A look at forensic dentistry – Part 1: The role of teeth in the determination of human identity *British Dental Journal* .2001; **190:** 359 - 366
8. Ilayperuma, I.; Nanayakkara, G. & Palahepitiya, N. A model for the estimation of personal stature from the length of forearm. Int. J. Morphol., 28(4):1081-1086, 2010.
9. Arthur M. LaVere, Keith R. Marcroft, Roland C. Smith and Robert J. Sarka, Denture tooth selection: An analysis of the natural maxillary central incisor compared to the length and width of the face: Part II Journal of prosthetic dentistry 1992; 67(6):810-
10. Adel Kamel Abdel-Malek, Afaf Mohamed Ahmed, Sawsan Abd El Aziz El Sharkawi, Nahed Abd El Maksoud Abd El Hamid. Prediction of stature from hand measurements. Forensic Science International. 1990; 46(3):181-87.
11. Ingrid HE. Rutishauser, Prediction of height from foot length use of measurement in field survey Arch Dis Child. 1968; 43:310-312
12. .Chantha K. Jayawardena1, Anushka P. Abesundara, Deepthi C. Nanayakkara and Malkanthi S. Chandrasekara Age-related changes in crown and root length in Sri Lankan Sinhalese. Journal of Oral Science. 2009; 51(4):587-592
13. Sterret JD, Oliver T, Robinson F, Fortson W, Knaak B, Russel CM. Width/length ratios of normal clinical crowns of maxillary anterior dentition in man. J Clin Periodontol. 1999; 26:153–157
14. Ozaki T, Satake T, Kanazawa E; Morphological significance of root length variability in comparison with other crown dimensions. II. Correlation between crown and root measurements. J Nihon Univ Sch Dent 1988; 30:11-21.
15. Henderson AM, Corruccini RS (1976) Relationship between tooth size and body size in American Blacks. J Dent Res.1976; 55:94-96
16. Dr. Sonali Khanapurkar, 2 Dr.Ashish Radke "Estimation of stature from the measurement of foot length, hand length and head length in Maharashtra region." Indian Journal of Basic & Applied Medical Research. 2012; 2(1): 77-85
17. T Stanley M. Garn And Arthur B. Lewis Tooth size body size and "Giant" Fossil Man.American Anthropologist. 2009; 60(5): 874-880

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JOURNAL of FORENSIC ODONTO-STOMATOLOGY

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SECTION IDENTIFICATION

Can mandibular lingual canals be used as a forensic fingerprint?

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ABSTRACT
Objectives: This study aimed to identify whether the lingual canals of the mandible can be used as a unique fingerprint when dealing with forensic victim identification.
Materials and Methods: The study consisted of two parts; an observational part and an objective image analysis part. In the observational part a total of 100 in vivo high resolution CBCT datasets of human mandibles were included in the process of simulated matching of ante-mortem (AM) and post-mortem (PM) data. For the objective image analysis part 10 dry human mandibles were scanned with 2 different Cone Beam Computed tomography (CBCT) machines. In the observational part of the study trained observers attempted to correctly identify matching pairs of images taken from the same mandible out of a series of 100 mandibles. The aim was to simulate matching of the neurovascular structures on AM and PM mandibular midline images and determine the percentage of mandibles identified correctly. In the objective image analysis part, simulated matching was carried out using a specific CBCT dataset acquired to mimic a PM dataset and 10 datasets acquired from a different CBCT device which served as the source of potential AM cases. Comparison between AM and PM datasets resulted in the matching of the AM data and PM data obtained from the same mandible, leading to an assumed correct identification.
Results: The observational part of the study showed an average 95% correct identification of the mandibular midline neurovascular structures. Registration of mandibles resulted in perfect overlap of the same mandible from 2 different CBCT machine with an error distance equalling zero, while the registration of different mandibles deviated on average error distance 0.13mm to 0.18mm.
Conclusion: The percentage of fit for the simulated AM and PM data of the same mandible was 100%. This finding together with the significant deviations noted for the non-matching cases, may have a potential role in forensic identification in the same way that fingerprints are recognised as being a unique identifying feature.

KEYWORDS: mandibular lingual canals, forensic odontology, victim identification, finger print.

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INTRODUCTION

The degree of uniqueness as determined by the morphology of the various dental structures is an essential feature used in forensic odontology especially in cases involving human identification.[1] The mandible is the strongest bone of the facial skeleton and is often the best preserved component after death. In mass disasters such as air crashes, wars, railway accidents and floods it is sometimes necessary to use unknown variables to describe the skeletal remains in order to establish victim identification.[2]

Interest in anatomical features and anatomical variations in the human mandible has increased in recent years due to the widespread use of cone-beam computed tomography (CBCT).[3,4] This imaging technique generates multiple high quality images enabling three dimensional (3D) visualization and complete osseous anatomical information. In forensic dentistry CT is often used for purposes of identification; numerous studies reported in the literature have used CT as auxiliary imaging method in the identification of unknown decedents. [5-8] CBCT is a relatively new CT system designed to focus on the head and neck region; an X-ray beam and detector system move around the part of the body being examined. CBCT is the preferred choice of methodology for diagnosis in almost all fields of dentistry including endodontics, orthodontics, periodontics, maxillofacial surgery and forensic dentistry.[9] CBCT is a more compact and cost-effective methodology when compared with systems based on multi-detector computed tomography (MDCT) and loses none of the reliability and accuracy of the MDCT images. [10-14]

Several techniques are available and used for purposes of identification.[15-19] This study addresses forensic victim identification when only limited PM material is available (e.g. mandibular fragments found in the PM datasets).The fact that US officers leaving for international missions in areas at risk receive a CBCT prior to departure to serve as an AM identification dataset has further triggered the present study.

While teeth have been proven to be valuable sources of information in disaster victim identification, the potential value of mandibular bony fragments has not yet been evaluated. Previous research has indicated that the mandible contains many accessory foramina and canals, particularly on the lingual side, with a significant anatomical variation amongst individuals.[3,20] Accessory foramina on the lingual side of the mandible can be divided into two main groups, namely medial and lateral lingual foramina.[3,21] The mandibular midline foramina are variable in number, size, intraosseous canal structures and morphology.[22,23] The significant variations in appearance make these midline structures unique for a particular individual.[24]

It might thus be hypothesized that these mandibular midline neurovascular canal structures might serve forensic identification, considering the unique appearance in each individual. This study, using both an observational and an image analysis approach, aimed to assess the appearance of the mandibular midline neurovascular canal structures and to determine whether perfect matching of simulated ante-mortem (AM) and post-mortem PM datasets could be demonstrated. If so this could be considered as a forensic fingerprint.

MATERIAL AND METHODS

The study, based on CBCT image datasets of in vivo and ex vivo mandibular samples, consisted of two parts; an observational part and an image analysis part.

For the observational part, a total of 100 in vivo high resolution CBCT datasets (3D Accuitomo 170, J.Morita, Kyoto, Japan) of human mandibles were included in the process of the simulated matching of ante mortem (AM) and post mortem (PM) data. Consecutive CBCT scans of human mandibles were selected retrospectively from patients referred to the Dentomaxillofacial Radiology Centre (University Hospitals, University Leuven). Ethical approval was obtained from the local Commission for Medical Ethics of the University Hospitals Leuven: S57587.

A total of 146 CBCT datasets were evaluated, with 46 of these being excluded. The exclusion criteria were:

1- Inadequate CBCT image quality (patient movement, operator error, etc).
2- Fracture in the lower jaw;
3- Any pathological lesions in the interforaminal region of the mandible.

The age range of the patients in the remaining 100 CBCT datasets, which were included in the present study, was 19-78 years with mean value of 45years. These 100 CBCT scans, obtained from the 3D Accuitomo CBCT (J.Morita, Kyoto, Japan) with a voxel size 0.08mm, were reformatted using the i-Dixel (J.Morita, Kyoto, Japan) software tools in order to obtain cross-sectional images for the mandibular midline showing the lingual canals.

In addition, 10 dry human mandibles were scanned with 2 different CBCT machines (Promax 3D Mid, Planmeca, Helsinki, Finland with the following exposure parameters 90kV, 10mA and volume size 40 x 50 mm; 3D Accuitomo 170 using 90kV,8mA, and volume size 40 x 40 mm).

Simulated matching of AM and PM data

The study was carried out to assess the usefulness of the mandibular midline neurovascular structures to serve as a forensic fingerprint. As indicated this was done in two parts, an observation part and an image analysis part. In the observational part, reformatted cross-sectional images were prepared for all mandibles. These views were then anonymised and labelled by the operator. The views were then mixed randomly and inserted into selection charts presented as slides in a regular PowerPoint file. Each PowerPoint slide contained 12 views representing 11 different mandibles. Only 2 of the 12 cross-sectional views presented on each PowerPoint slide were derived from the same mandibular midline.

Five trained observers (four dental radiologists and one oral surgeon) were presented with 100 PowerPoint slides of 12 different cross-sectional views of the symphyseal region and midline of randomly selected mandibles. A training session was organized prior to the final observations for explanation of the procedure. Observers were seated in front of an observational monitor, and asked to identify and note down the matching pairs of mandibles in each selection chart (Fig. 1). Two weeks later a similar second observational trial was carried out but used a different set of selection charts prepared following re-randomised of the views that had been used previously in the first trial.

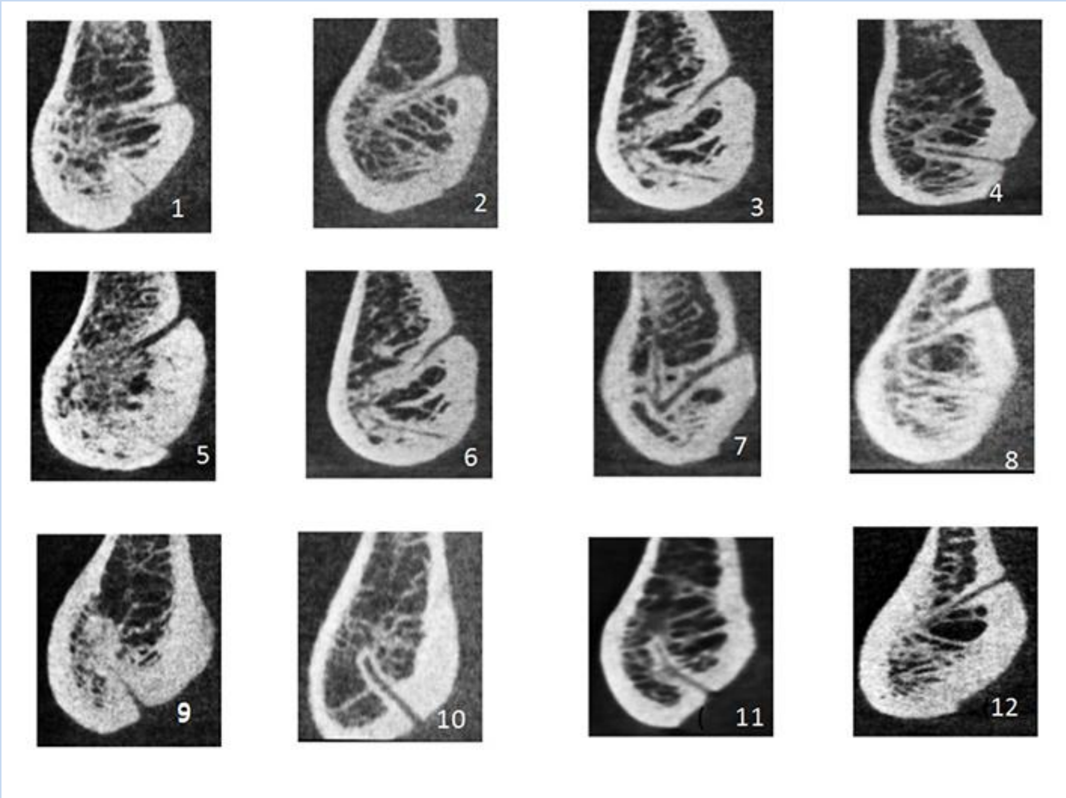


Fig.1: Observational chart with 12 views of 11 different mandibles, with only 2 cross-sectional views on the plate deriving from one and the same mandibular midline.

Image analysis part of the simulated AP/PM matching

In this part, the dataset of one mandible scanned with the system 3D Accuitomo CBCT (J.Morita, Kyoto, Japan) was selected as the PM case and the datasets of 10 mandibles scanned with the system Promax 3D (Finland) were selected as the AM cases. The mandible scanned with the system 3D Accuitomo CBCT was also included within the complement of ten mandibles scanned with the system Promax 3D (Finland). Registration was carried out between the post-mortem dataset and each of the ten ante-mortem datasets using software tools (MIMICS v16.0 and 3-matic v8.0, Materialise, Leuven, Belgium).

The procedure to match the AM and PM datasets used MIMICS software As a first step a bone mask was created using a global threshold value. The region of interest (ROI) was selected by cropping this mask around the midline symphyseal structures. From this ROI, a surface rendered 3D model was calculated and saved as an STL file.

To ensure a good starting position with the 3-matic software a global registration was necessary using two 3D models. This was achieved by performing a manual registration where the focus was on the visible overlap of the midline symphyseal structures (Figs. 2 and 3). A global registration was subsequently carried out; this procedure automatically moves one mandible with respect to the other trying to minimize the distance error between the two models. After the registration procedure, a part comparison analysis was performed in order to assess the differences between two mandibles. This was a point-based method where the deviations are calculated between the two models to allow AM and PM matching.

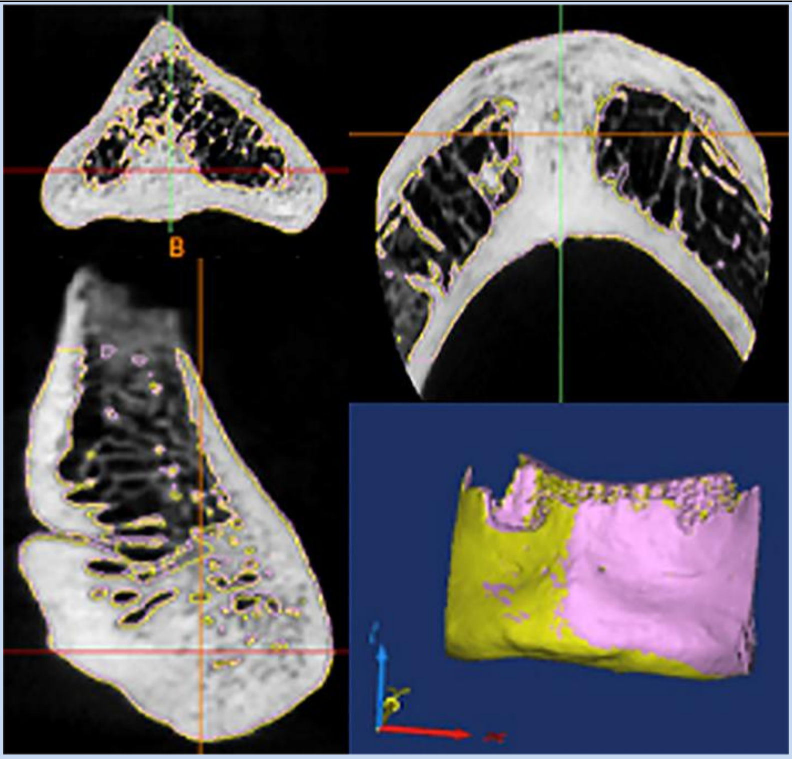


Fig. 2: Manual registration for the same mandible with two different machine showing perfect overlap where 3D model shows a yellow color represent the post mortem case and the pink representing the ante mortem case.

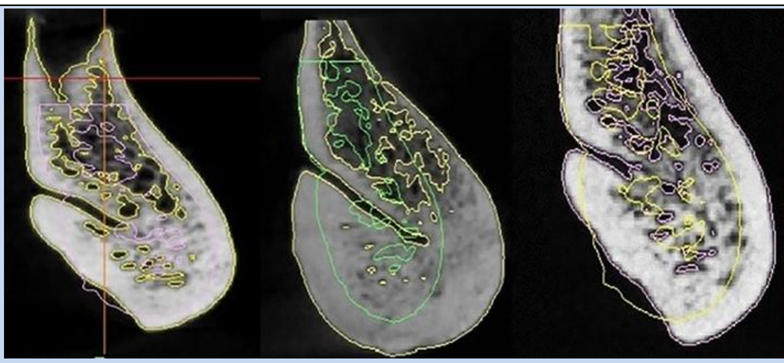


Fig. 3: Cross-sectional views of different ante mortem mandibles. The contour around the bone shows the mask inside the ROI. The second contour is from the post mortem case which is manually registered at the level of the lingual canals. It is clearly seen that there is no perfect overlap.

RESULTS

Observational part

In the first observation test using 100 PowerPoint slides each depicting 12 different cross-sectional views of the symphyseal region and midline of randomly selected mandible three observers achieved 100% success in achieving correct identification of the matching pairs, while 2 observers achieved a success rate of 92%. In the second observation test the average of matching was 95%. Intra and inter-observer agreement was good (95% agreement on average). Results of the matched pairs for identification is shown in Fig.4 for all 5 observers. Inter- and intra-observer agreement was 99% and 96.1% respectively.

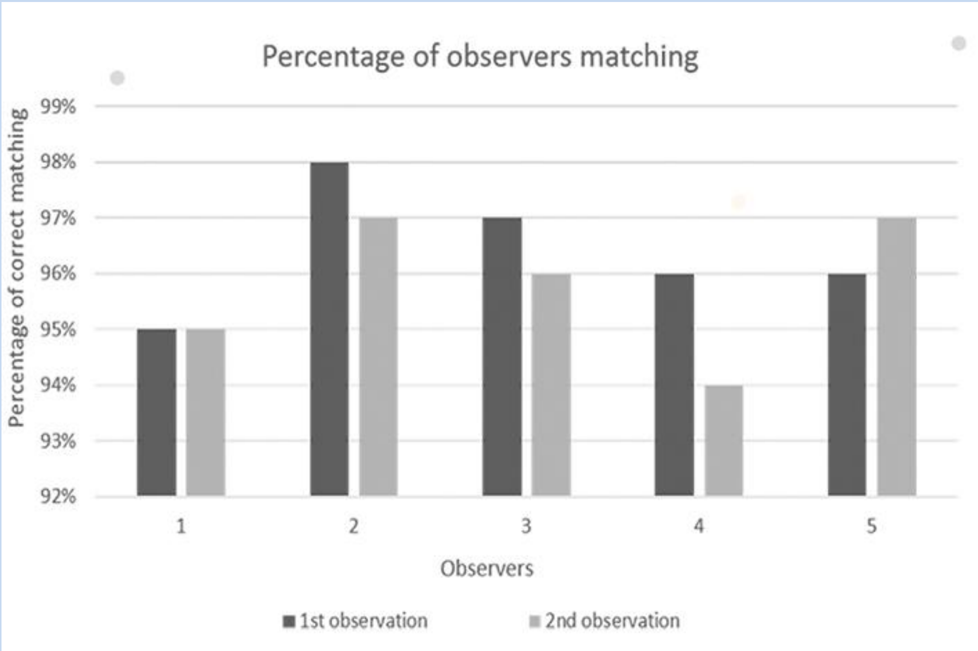


Fig. 4: Results of the observation of the matched mandibles of the 100 in vivo cases of the mandible.

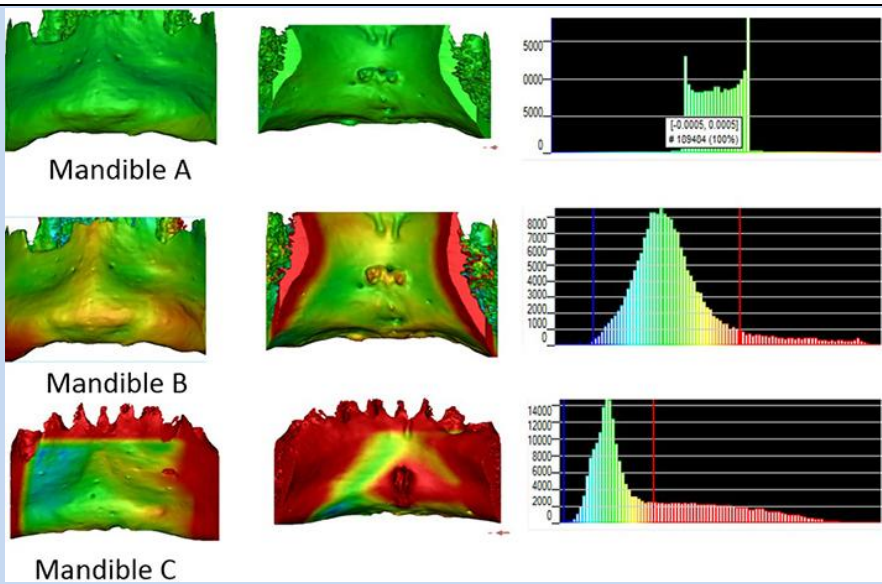


Fig. 5: Mandible A: The 3D color coded model after part comparison analysis showing values located around 0mm deviation, which is represented by the green color.The histogram ranges from -0.0005mm to 0.0005mm and the sliders fixed at -0.0005mm and 0.0005 mm.Mandible B and C: 3D models showing the minimum and maximum deviation between different mandibles and the histogram range is going from the minimum and maximum deviation found in the part analysis however the threshold sliders for defining the color code are fixed at -2.00mm to 2.00mm.

Image analysis part

The registered post-mortem mandible CBCT dataset showed 100% overlap and fit at the midline symphyseal area with the ante-mortem images of the same mandible obtained on the other CBCT machine; the error distance after global registration was 0.0 mm.

Following global registration the registered images of two different mandibles never showed a perfect fit: there was always an error distance after global registration. The error distance between the registered different mandibles ranged from 0.13 mm to 0.18 mm

The part comparison analysis for the registered mandibles showed mean values from 0.14±1.34 mm to 0.53±2.13 mm; however the part comparison for the same registered mandible from two different machines showed 0 mm. In Table 1, the mean error distance after global registration is shown together with the mean deviation obtained with a point-base part comparison. The simulated AM and PM data deriving from the same mandible, showed a zero deviation, indicating a perfect overlap or 100% matching data. The median value and standard deviation values are also presented. From the part comparison, it is possible to create a colour-coded 3D model where the blue colour represents a negative value and the red colour represents the maximum value.

Table 1: Measurement of mean error distance from the global registration and part comparison analysis of the mandible representing the post mortem case with the other 10 mandibles representing ante mortem.

Registered mandible	Error distance in mm	Median in mm	Mean in mm	SD in mm
PM 1 with AM 1	0.00	0.00	0.00	0.00
PM 1 with AM 2	0.18	0.15	1.09	2.31
PM 1 with AM 3	0.17	0.15	0.01	0.7
PM 1 with AM 4	0.17	0.14	0.56	1.34
PM 1 with AM 5	0.13	0.43	0.99	1.73
PM 1 with AM 6	0.17	0.53	1.84	2.75
PM 1 with AM 7	0.17	0.45	1.99	3.1
PM 1 with AM 8	0.18	0.44	1.36	2.27
PM 1 with AM 9	0.17	0.31	1.31	2.33
PM 1 with AM 10	0.17	0.53	1.26	2.13

PM: Post mortem; AM: Ante mortem

For Mandible A (Fig.5) a colour-coded 3D model is presented together with the histogram of the deviations from the identical AM and PM mandible. The 3D colour coded model, depicting the buccal and lingual sides of the mandible, together with the histogram following part comparison analysis of the same mandible scanned with two different machines, demonstrates a single green colour code; the green colour code represents a 100% match.

For Mandible B (Fig.5) a colour-coded 3D model is presented compiled from both AM and PM data. The 3D colour coded model, depicting the buccal and lingual sides of the mandible, together with a histogram following part comparison analysis of the two different mandibles demonstrated a minimal amount of error distance and showed a wide area of matching green colour. There were limited unmatched area coloured red. The histogram ranges from -2.71 mm to 3.03 mm .

For Mandible C In (Fig.5) a colour-coded 3D model is presented compiled from both AM and PM data. The 3D colour coded model, depicting the buccal and lingual sides of the mandible, together with a histogram following part comparison analysis of two different mandibles with maximal amount of error distance demonstrated a wide area of unmatched colour. There were wide areas of red colour and limited areas of green color. The histogram ranges from -2.24 mm to 14.11mm.

DISCUSSION

The mandible is one of the strongest bone in human face and the best preserved after death. It can be of assistance for purposes of personal identification. The present study evaluated the anatomical variability of the mandibular neurovascular canals in the midline symphyseal region and sought to establish whether this feature could act as a forensic fingerprint.

This study showed the differences in shape and direction of the lingual canals on CBCT images (Fig.6). Observers were able to identify the matched mandibles according to the specific anatomy of these lingual canals (shape, direction, and angulations).

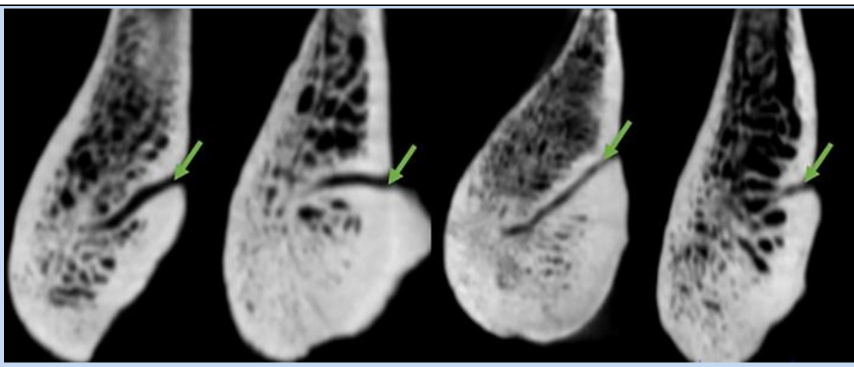
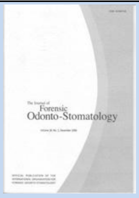


Fig. 6: Cross sectional view of different mandibles showing multiple shapes and directions of the lingual canals.

The observation study on the dry in-vitro mandibles showed a high agreement between the observers to distinguish the matched mandibles presented on the PowerPoint slides depicting cross-sectional images at the midline area containing the lingual canals. One observer achieved a success rate of 100% to match mandibles correctly. The other observers had difficulties in matching one of the mandibles. It was noticed that the same mandible was always wrongly classified and thus difficult to match. The reason for this might be the fact that this mandible showed less distinct and developed canal structures.

The high level of agreement noted between the observers to identify the lingual canals in each mandible was important; it “flagged up” the potential of the lingual canals as an aid to identification by comparison of ante-mortem and post-mortem CBCT data. Liang et al.,[25] described the anterior region of the mandible and its lingual side and showed



that there was a difference in number of the lingual foramina.

The existence of the midline lingual foramina with neurovascular bundles was confirmed by a comparative study of histological findings and high-resolution magnetic resonance imaging.[26] The observation study on the patient CBCT data demonstrated that two views of the same mandible could be matched by careful consideration to the lingual canals. A success rate of 96 % was achieved.

The registration of the mandible representing the ante-mortem case with the identical mandible scanned with another CBCT system representing the post-mortem case showed a perfect fit and overlap in the midline neurovascular canals. The mean error distance obtained with global registration was 0mm implying a perfect (100%) fit between AM and PM data of the same mandible.

The registration of different mandibles representing ante-mortem cases and post-mortem cases did not demonstrate an overlap of 100%. The distance error ranged from 0.13 mm to 0.18 mm.

It can be concluded that every mandible has a specific anatomical structure at the midline including the lingual foramen and the neurovascular bundles. Against this background it is proposed that the symphyseal region with its neurovascular canals can be used for differentiation and identification of human mandibles. Further studies using larger samples should be considered.

CONCLUSIONS

There is variability demonstrated within the morphology of the human mandibular midline neurovascular canals. This could be a useful aid in cases of human identification.

There is a distinct contrast between the almost perfect success rate achieved in matching corresponding ante-mortem and post-mortem data compared with the significant deviations noted in the success rate to match different ante-mortem and post-mortem data.

Against this background the mandibular midline neurovascular canals could be of assistance in forensic dentistry in the same way that fingerprints are recognised as being a unique identifying feature.

REFERENCES

1. Silva RF, Prado MM, Botelho TL, Reges RV, Marinho DEA. Anatomical variations in the permanent mandibular canine: forensic importance. *RSBO* 2012;9(4):468-73.
2. Pillai TJ, Devi TS, Devi CKL. Studies on human mandibles. *IOSR Journal of Dental and Medical Science 2014;13(1):8-15.*
3. Murlimanju BV, Prakash KG, Samiullah D, Prabhu LV, Pai MM, Vadgaonkar R, Rai R. Accessory neurovascular foramina on the lingual surface of mandible: incidence, topography, and clinical implications. *Indian J Dent Res* 2012;423: 433.
4. Oliveira-Santos C, Souza PH, De AzambujaBerti-Couto S, Stinkens L, Moyaert K, Van Assche N, Jacobs R. Characterization of additional mental foramina through cone beam computed tomography. *J Oral Rehabil* 2011;38:595-600.
5. O'Donnell C, Iino M, Mansharan K, Leditscke J, Woodford N. Contribution of postmortem multidetector CT scanning to identification of the deceased in a mass disaster: Experience gained from the 2009 Victorian bushfires. *Forensic Sci Int* 2011;205:15-28.
6. Thali MJ, Markwalder T, Jackowski C, Sonnenschein M, Dirnhofer R. Dental CT imaging as a screening tool for dental profiling: advantages and limitations. *J Forensic Sci* 2006;51:113–119

7. Birngruber CG, Obert M, Ramsthaler F. Comparative dental radiograph identification using flat panel CT. *Forensic Sci Int* 2009:e31-e34.
8. Jackowski C, Wyss M, Persson A. Ultra high-resolution dual source CT for Forensic dental visualization-discrimination of ceramic and composite fillings. *Int J legal Med* 2008;122:301-307.
9. Miraclea AC, Mukherji SK. Cone beam CT of the Head and Neck Part 2: Clinical Applications. AJNR 2009;30:1285-1292.
10. Marmulla R, Wörtche R, Mühling J, Hassfeld S. Geometric accuracy of the New Tom 9000 Cone Beam CT. *Dentomaxillofac Radiol* 2005;34:28-31.
11. Biwasaka H, Aoki Y, Tanijiri T, Sato K, Fujita S, Yoshioka K, Tomabechi M. Analyses of sexual dimorphism of contemporary Japanese using reconstructed three-dimensional CT images-curvature of the best-fit circle of the greater sciatic notch. *Leg Med (Tokyo)* 2009;11:S260-S262.
12. Timock AM, Cook V, McDonald T, Leo MC, Crowe J, Benninger BL, Covell DA Jr. Accuracy and reliability of buccal bone height and thickness measurements from cone-beam computed tomography imaging. *Am J Orthod Dentofacial Orthop* 2011;140:734-744.
13. Gamba TO, Oliveira ML, Flores IL, Cruz AD, Almeida SM, Haiter-Neto F, Lopes SL. Influence of cone-beam computed tomography image artifacts on the determination of dental arch measurements. *Angle Orthod* 2014;84:274-278.
14. von See C, Bormann KH, Schumann P, Goetz F, Gellrich NC, Rücker M. Forensic imaging of projectiles using cone-beam computed tomography. *Forensic Sci Int* 2009;190:38-41.
15. Kharoshah MA, Almadani O, Ghaleb SS, Zaki MK, Fattah YA. Sexual dimorphism of the mandible in a modern Egyptian population. *J Forensic Leg Med* 2010;17:213-215.
16. Slaus M, Strinović D, Pećina-Slaus N, Brkić H, Balicević D, Petrovecki V, Pećina TC. Identification and analysis of human remains recovered from wells from the 1991 War in Croatia. *Forensic Sci Int* 2007;171:37-43.
17. El Morsi DA, Al Hawary AA. Sex determination by the length of metacarpals and phalanges: X-ray study on Egyptian population. *J Forensic Leg Med* 2013;20:6-13.
18. Sachan K, Sharma VP, Tandon P. A correlative study of dental age and skeletal maturation. *Indian J Dent Res* 2011;22:882.
19. Eshak GA, Zaher JF, Hasan EI, El-Azeem Ewis AA. Sex identification from fingertip features in Egyptian population. *J Forensic Leg Med* 2013;20:46-50.
20. Sutton RN. The practical significance of mandibular accessory foramina. *Aust Dent J* 1974;19:167-173.
21. Katakami K, Mishima A, Kuribayashi A, Shimoda S, Hamada Y, Kobayashi K. Anatomical characteristics of the mandibular lingual foramina observed on limited cone-beam CT images. *Clin Oral Implants Res* 2009;20:386-390.
22. Vandewalle G, Liang X, Jacobs R, Lambrichts I. Macroanatomical and radiographic assessment of the superior and inferior genial spinal foramina and their bony canals .*Int J Oral Maxillofac Implants* 2006;21:581-586.
23. Liang X, Jacobs R, Lambrichts I,Vandewalle G, Van Oostveldt D, Schepers E, Adriaensens P, Gelan J. Macroanatomical and histological assessment of the content of superior and inferior genial spinal foramina and their bony canals. *Dentomaxillofac Radiol* 2005;34:362-368.
24. Ennis LM. Roentgenograph variation of the maxillary sinus and the nutriment canals of the maxilla and the mandible. *Int J Orthodont Oral Surg* 1937;23:173-193.
25. Liang X, Jacobs R, Lambrichts I, Vandewalle G. Lingual foramina on the mandibular midline revisited: a macro anatomical study. Clin Anat *2007;*3:246-251.
26. Jacobs R, Lambrichts I, Liang X, Martens W, Mraiwa N, Adrianensens P, Gelan J. Neurovasculaization of the anterior jaw bones revisited using high-resolution magnetic resonance imaging. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 2007;103:683-693.

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