

Use of Intraoral Three-dimensional Images for the Identification of Dental Morphological Traits Related to Ancestry Estimation

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Abstract

Victim identification through dental features is one of the main objectives of forensic dentistry. In circumstances where information regarding antemortem dental records is missing, reconstruction of a biological profile can be useful as a first step toward personal identification. This reconstructive method provides valuable information, namely regarding the individual's ancestry, through the detection and degree of expression of dental morphological traits, which may help to restrict the number of candidates for identification. Technological advances allowed the development of alternative methods for dental evaluation, that complement or substitute those already in use in clinical practice. Among these, intraoral three-dimensional (3D) images are increasingly used in dentistry, as they have a high level of accuracy and are easy to obtain and store. However, a fundamental question regarding forensic dentistry is whether they allow recognition and analysis of dental morphological traits in detail, namely those related to ancestry. In this study, we evaluated 20 teeth morphological features using intraoral 3D imaging from 77 individuals from Northern Portugal. Our results showed that it was possible to identify and classify a large part of the main morphological traits used in the estimation of ancestry. As these 3D images present sufficient morphological detail to be classified, we believe that future applications of this technique can be expected in forensic dentistry.

Keywords: Ancestry, dental traits classification, forensic anthropology, forensic dentistry, human identification, intraoral scanning, three-dimensional images

INTRODUCTION

Identification through dental evidence is one of the main objectives of forensic dentistry. Based on the detection of dental features, comparative techniques allow the identification of victims by crossing antemortem and postmortem data.^[1-3]

When there is no clear idea of the victim's identity (for example, in open mass disaster situations or when unidentified bodies are found), the so-called reconstructive methods are applied, which enable the construction of a biological profile (ancestry, sex, age at death and possibly, approximate height). A closer approximation to the individual's identity is then achieved, limiting the number of potential candidates.^[1]

Regarding ancestry, Forensic Dentistry and Forensic Anthropology have developed methods to find information from certain observable traits, present in the biological remains.^[4-7] It is known that there is variation in the frequencies

of dental morphological traits between populations, such as shovel-shaped incisors in Asian or Native American populations, or Bushmen canine in sub-Saharan Africa.^[8,9] Therefore, it is recommended that ancestry should be determined initially since there are interethnic variations that can influence the other parameters of the biological profile.

The development of new technologies in clinical practice has resulted in an increase in the number of tools available

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for dental analysis. This is the case of the intraoral scanner, which is being used more and more frequently. A simple scan allows to perform a three-dimensional (3D) reconstruction of the patient's oral cavity, and subsequently to analyze the adequacy of treatments. From a technical point of view, these images seem to have extremely high levels of accuracy.^[10-13] However, there are hardly any studies that take advantage of these 3D dental images in a forensic context, and even less those applied to population studies.^[2,14] There is, then, a considerable gap of information about its usefulness in dental analysis, for identification purposes.

The fast, easy, and accurate collection of intraoral 3D images, together with the possibility of ample digital storage and prompt exchange of information, are appealing aspects for potential forensic applicability. A fundamental issue regarding 3D images is to know if dental morphological traits are recognizable and analyzable in detail, namely those related to ancestry.

This work aims to establish the basis for the validation of 3D intraoral images in dental morphological traits studies for forensic purposes; it is intended to evaluate whether these images allow the detection and observation of morphological traits in sufficient detail to be classified.

MATERIALS AND METHODS

Sample and ethics

The sample consisted of 77 3D images obtained from patients of Portuguese nationality, (34 males and 43 females, aged between 15 and 52 years old), provided by a dental clinic (Portugal). This study was carried out following all procedures in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Written informed consent was obtained from all patients for scientific studies.

Devices and software

The intraoral images were obtained with an iTero[®] intraoral 3D scanner, from the company Align Technology. The images in "stl" format were opened with the help of the online platform "mycadent.Com." The MacOS Sierra (version 10.12.6) Preview software (Apple inc., U.S.A) was also used to observe and analyze the images.

STUDY DESIGN

This was a retrospective transversal observational study. The exclusion criteria were: Patients who had visible restorations or treatments that affected the studied trait, and patients with mixed dentitions (only permanent teeth with the studied trait were considered).

The Federation Dentaire Internationale numbering system was used to identify the teeth. For the selection of traits studied, nonmetric dental traits were chosen from the crowns of

permanent teeth. The criteria used was based on the Arizona State University Dental Anthropological System (ASUDAS) reference classification ASUDAS.^[4,6] A total of 20 coronary traits with forensic interest were selected:

- Six traits inherent to the upper incisors: Labial convexity, shoveling, double-shoveling, interruption groove, variations of the upper lateral incisors, tuberculum dentale (also present in the upper canines)
- Three traits inherent to the upper canines: Tuberculum dentale, Bushman canines, accessory distal canine crest (also present in the lower canines)
- Three traits inherent to the upper premolars: Accessory premolar crest (also present in the lower premolars), mesial and distal accessory cusp of the upper premolar, uto-aztecan premolar, odontoma (also present in lower premolars)
- Eight traits inherent to upper molars: Metacone, hypocone, bifurcated hypocone, cusp 5, marginal ridge tubercle, Carabelli's cusp, parastyle.

RESULTS

Sixteen of the 20 traits sought were found, which showed different degrees of expression. No examples of lip convexity, Bushman's canine, Uto-Azteca premolar, and premolar odontoma were found. The remaining traits are shown in Figure 1.

The Carabelli's cusp is a characteristic with variable and

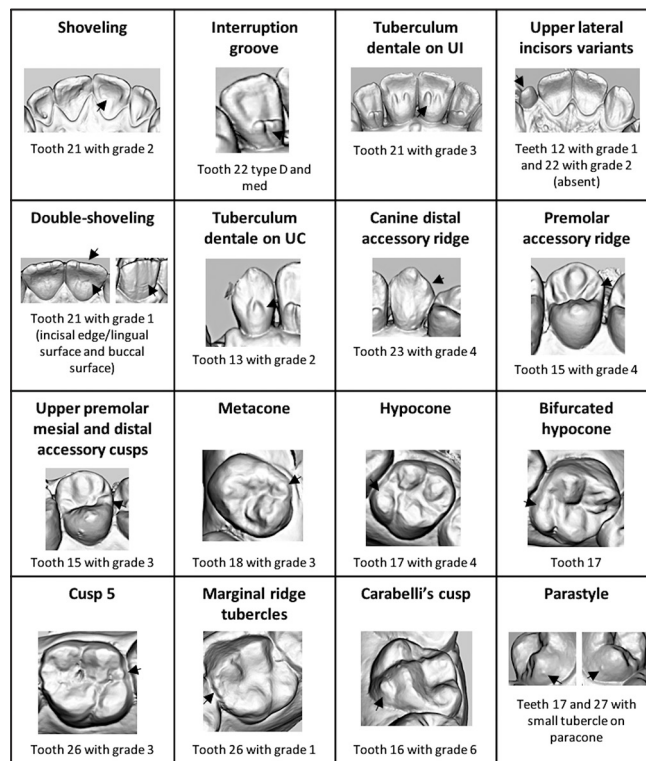


Figure 1: Two-dimensional images of dental morphological traits of the crowns related with ancestry, taken from the three-dimensional images of the analyzed individuals

frequent expression in the European population. It was chosen for a more detailed observation of its 7 degrees of expression, according to the ASUDAS classification. The partial images taken from the 3D reconstructions show that it is possible to observe a high level of detail (favored by the fact that they can be manipulated in the three dimensions), which allows a classification without great difficulty [Figure 2]. Finally, Table 1 shows the frequencies of the Carabelli's cusp in the studied population.

DISCUSSION

The aim of this study was to assess whether intraoral 3D images allow the detection and observation of detailed nonmetric dental traits for application purposes in forensic dentistry. The chosen dental morphological features were clearly identified and proved to be classifiable, even when their degree of expression was very low [see as examples, Parastyle in Figure 1, and Carabelli's cusp grades, in Figure 2].

Not all traits were identified, for two main reasons: Some traits are more strongly associated with specific ethnicities (for example, the Bushmen canine in sub-Saharan African populations, or the Uto-Azteca premolar in southwestern Native American populations), or because they are rare in the general population (this is the case of premolar odontoma

and labial convexity).^[6,8,15] Other traits, however, are easily distinguishable (Carabelli cusp, tuberculum dentale, accessory distal crest of the canines, accessory distal crest of the premolar, hypocone, metacone, and cusp 5), probably because they are more frequent in European populations.^[4-6,8]

The observation of 3D images (present study) and the classic visual examination of traits are different approaches. The frequencies obtained with each method should not be directly compared, since the perception of the morphological trait expression by the operator could be slightly different. However, to perceive the level of proximity with the frequencies of other studies, we looked at a very common trait, such as the Carabelli's cusp. Most of the authors take into account a threshold (breakpoint) in the frequencies of certain traits with different degrees of expression, since differences between populations are more evident this way, or to avoid problems in the interpretation of the feeble expression. This is the case of the Carabelli cusp, in which is used grade 5+ (frequencies considered range from grades 5 to 7) or grade 3+ (frequencies considered range from grade 3 to 7). Previous studies of a late modern/contemporary collection from Northern Portugal (by visual examination) showed a frequency of 12.8% of Carabelli's cusp in grade 5+ ($n = 87$), compared to the 13% obtained in the present study ($n = 77$).^[15] Another study in a modern European population showed a frequency of 21.6% of Carabelli's cusp in grade 3+ ($n = 728$), compared to the 23.4% obtained in the present study ($n = 77$).^[8] The values obtained with one or another method seem to be similar, indicating a clear trend towards the validity of the use of 3D images for this analytical purpose.

The 3D digitalization of the oral cavity is a reality in the current dental clinical activity and is gaining interest in the scientific community, namely as a Disaster Victim Identification technique.^[2] The 3D technology has numerous advantages, such as the high reliability of the images obtained, the manipulation of the image in 3 dimensions, speed and reproducibility of the process, ease in handling the scanner, possibility of massive exchange of digital information, and easy storage. However, this technology has some aspects that require special attention to avoid misinterpretations (namely, the operator needs to have the dental medical knowledge to identify possible therapeutic alterations), or aspects regarding costs (high initial cost of the device and an eventual additional cost in the storage and maintenance of heavy digital images).^[10] Although visual examination of the material is the ideal form of evaluation, the availability of 3D images proves to be an excellent complementary method.

CONCLUSIONS

Intraoral 3D images allow to distinguish of dental morphological traits of the crown with forensic and/or anthropological interest; these images also provide enough detail to distinguish the different degrees of expression, enabling its classification. The analysis of 3D images obtained with the intraoral scanner

Table 1: Frequency of the Carabelli's cusp in the population under study

	Frequencies, <i>n</i> (%)
Grade 0	20 (26)
Grade 1	22 (28.5)
Grade 2	17 (22.1)
Grade 3	4 (5.2)
Grade 4	4 (5.2)
Grade 5	3 (3.9)
Grade 6	4 (5.2)
Grade 7	3 (3.9)
Total	77 (100)

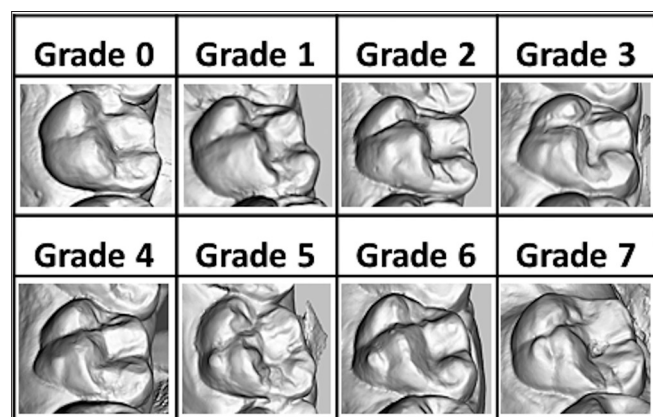


Figure 2: Classification of the Carabelli's cusp in the population under study, in its 7 degrees of expression, with degree 0 being its absence

proves to be an innovative technique, and future applications are expected in forensic dentistry.

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Conflicts of interest

There are no conflicts of interest.

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