Forensic Science International 289 (2018) 337–343

Contents lists available at ScienceDirect

Forensic Science International

journal homepage: www.elsevier.com/locate/forsciint

Accuracy of dental identification of individuals with unrestored permanent teeth by visual comparison with radiographs of mixed dentition

Ludovica Gorza*, Scheila Mânica

Centre for Forensic and Legal Medicine, School of Dentistry, University of Dundee, 3 Cross Row, Dundee, DD1 5HG, UK

ARTICLE INFO

Article history:
Received 29 September 2017
Received in revised form 4 March 2018
Accepted 5 June 2018
Available online xxx

Keywords:
Dental radiographs
Forensic odontology
Forensic identification
Mixed dentition
Unrestored teeth

ABSTRACT

Forensic dentistry plays a major role in human identification. Teeth carry individual characteristics that differ among different individuals. Dental radiographs depict reality objectively, being the most reliable tool for dental identification. The first aim of this study was to evaluate the accuracy of dental identification of individuals with permanent unrestored teeth by visual comparison with radiographs of mixed dentition. The second aim was to learn which anatomical features were compared by examiners with different backgrounds. A total of 19 forensic experts participated in a web-based questionnaire to assess identification of 12 simulated cases; each case required the radiographic comparison of 1 dental PM radiograph to 3 dental AM radiographs, of which only one was the correct match. The examiners were given four options following the ABFO guidelines: established identification, possible identification, insufficient data and exclusion; the participants also explained the reason for each of their conclusions. The accuracy of the methodology was 75,4%, the sensitivity was 53,5% and the specificity was 86,4%. Overall, there was a tendency of the observers to overlook non-dental characteristics. Not surprisingly, dental identification by visual comparison of radiographs was not immune to subjectivity and, even analysing the same category of features, different conclusions and consequently different percentages of accuracy were reached. When matching the correct AM radiograph, most examiners compared the root morphology of the first molars and the shape of the maxillary sinus. When one of the AM radiographs was not matched, the examiners mostly asserted that there was insufficient data to reach a conclusion due to the lack of distinctive and comparable features. With AM and PM radiographs showing different development stages, accuracy was correlated to the age of the AM radiograph.

1. Introduction

The identification of the living and of the dead is a human right to be guaranteed for ethical, cultural, religious and economic reasons. Not less important, it contributes to criminal investigations in case of violent and suspicious deaths. Teeth are primary identifiers and could lead to the certain identification or exclusion of an individual without the aid of additional factors [1]. Identification by dental means is one of the fields of expertise of a forensic dentist (FD) and it is useful in single cases as well as in mass disasters, when a significant number of bodies are recovered at the same time [2]. The pattern and combination of dental treatments, anatomic and pathologic features are hardly similar between different subjects [3,4]. Identification is conducted by comparing the post-mortem (PM) dental data collected during the autopsy to the ante-mortem (AM) dental records of alleged matches [1]. Intra-oral and extra-oral dental radiographs are often the key to this process, by objectively displaying anatomic and pathologic features that are not visible to the naked eye by external examination [5,6]. Visual comparison is the most inexpensive and commonly adopted method for the analysis of traditional films or digital radiographs for identification purposes. However, there are no standardized protocols and the final conclusion is susceptible to the personal interpretation of the operator, who might confirm or exclude identity based on a single trait [7,8]. Any scientific method that aims to produce evidence with medico-legal outcomes should follow the Daubert standard: be accepted by the scientific community, be repeatable, standardized and be subjected to peer-review and publication reporting an acceptable error rate [9]. Previous studies tested the accuracy of dental identification by

* Corresponding author.
E-mail address: gorzaludovica@gmail.com (L. Gorza).

https://doi.org/10.1016/j.forsciint.2018.06.004
0379-0738/

visual comparison of radiographs with unrestored dentitions within samples of similar age ranges [10–12], whereas studies considering wide time intervals between AM and PM radiographs mostly included restored permanent dentitions [13]. The first aim of the research was to test if manual radiographic comparison is an accurate identification methodology when the PM radiograph depicted permanent sound dentition, the AM and the PM radiographs were separated by a significant time-lapse and the AM radiograph dated back to the age of mixed dentition. The second aim was to investigate which anatomic features visible in panoramic radiographs were analysed by experts in forensic identification.

2. Materials and methods

A total of 100 forensic dentists (FD), forensic anthropologists (FA) and radiologists (R) were contacted via email to participate in a web-based survey. Volunteers were searched within University lecturers and forensic international organizations (ABFO, ABFA, BAFO, IOFOS). The field of expertise and the number of years of experience were self-reported in the survey; however, they were not asked to state the level of qualification (i.e.: MS, PhD) and the number of forensic identifications performed throughout their career. The radiographic database of three Italian private dental clinics were scrutinized. A total of twelve panoramic radiographs (OPGs) depicting complete shedding, permanent and unrestored dentition were selected as simulated PM radiographs; individuals who had received and completed an orthodontic treatment or had a fixed orthodontic retainer visible only in the PM radiograph were included; the OPGs of the same subjects showing mixed dentition with at least initial eruption of the first molar or the central incisor worked as simulated AM radiographs; if the deciduous teeth were decayed or filled but all permanent teeth were sound, the radiographs were included. Individuals with oral manifestations of genetic syndromes, dental agenesis, malformations of cranio-facial structures, cavities, fillings or other dental treatments of the permanent dentition and retained primary teeth in PM radiographs were excluded. Twenty-four more OPGs of children with mixed dentition and respecting the criteria were selected and worked as false matches or False Positive (FP). The time-lapse between the AM and PM radiographs was between 3 and 18 years. The age of the individuals of the AM radiographs ranged between 8 and 13 years. The selected radiographs, if traditional films, were photographed using a Nikon D90 camera (© 2017 Nikon Corporation) and digitalized. The web-based survey was created on Google Forms (© 2015 Google Inc.) and was only accessible by private invitation. The questionnaire included twelve cases, each one showing one PM radiograph paired to three AM radiographs; all the radiographs were cut into halves at the midline of both dental arches using Microsoft Foto Windows 10 (© 2017 Microsoft Corporation); consequently, six cases showed the right side and six the left side of the original radiographs. The examiners were not informed that only one AM radiograph in each case belonged to the same individual as the PM. Because the first aim of the study was to test the accuracy of dental identification by visual comparison of radiographs alone, no extra medical or dental information about the subjects was provided. Each section included one multiple-choice question and one open-ended question for each AM radiograph; the former asked to reach a conclusion of identification or exclusion providing four options, according to the ABFO guidelines (established identification, possible identification, insufficient data, exclusion) [14]; the latter asked to explain the reason for the conclusion with no word-limit or directions of any kind. Radiographs of each section were available for download, zooming or digital enhancement by accessing an on-line folder (© Dropbox Inc). The examiners could not proceed further before filling all the questions within each case. The Author who collected the radiographs and prepared the questionnaire did not participate. The acquisition of the answers was automatic once all the sections were completed and the results were immediately and exclusively visible to the Authors on an Excel spreadsheet. The answers to the multiple-choice question were analysed quantitatively to calculate the total number of correct identifications or True Positive (TP), correct exclusions or True Negative (TN), incorrect identifications or False Positive (FP) and incorrect exclusions or False Negative (FN) of each operator. The percentages of sensitivity, specificity, accuracy by examiner and by case were calculated. The level of confidence of the examiners when answering to the multiple-choice questions was also measured: the percentages of Established (E) and Positive (P) identifications were calculated for both TP and FP; the percentages of Insufficient Data (IND) and Exclusions (X) were calculated for both TN and FN. Additionally, a linear regression model was applied to investigate the correlation between accuracy and AM-PM time lapse, age of the AM radiograph and experience of the examiners.

The answers to the open-ended questions were analysed qualitatively by thematic analysis to investigate which features were compared by examiners according to their performance [15]; firstly, the examiners were divided into four groups (1–4) according to the percentage of sensitivity and specificity: the cut-off point chosen was 80%. Only one type of answer was analysed for each group of examiners: explanations to the TP (Type A) from examiners with sensitivity equal to or higher than 80% (Group 1); explanations to the FN (Type B) from examiners with sensitivity lower than 80% (Group 2); explanations to the TN (Type C) from examiners with specificity equal to or higher than 80% (Group 3); explanations to the TP (Type D) from examiners with specificity lower than 80% (Group 4). Thematic analysis was performed on the four types of questions by searching for specific keywords in the text. Two main categories were established. The first category included “dental features”; subcategories I were “anatomy” and “number”; while sub-categories II were “type of tooth” and “part of the tooth”. The second category was “non-dental features” and subcategory I was “anatomy”; which collected all the responses quoting any cranio-facial structures other than teeth. It was then calculated the percentage of times that the features from each category and sub-category were mentioned.

3. Results

A total of 19 volunteers, 15 FD and 4 FA, accepted and completed the questionnaire; 3 FD and 2 FA from the UK, 1 FA from USA, 4 FD from Canada, 4 FD from Brazil, 1 FD from Mexico, 1 FA from Italy, 1 FD from Iceland, 1 FD from Mauritius and 1 FD from Australia. The number of years of experience ranged between 1 and 30 years (Table 1): only 2 out of 19 examiners (11%) had less than 2 years of experience; 10 examiners (57%) had between 2 and 15 years; 6 examiners (31%) had at least 16 years, with one examiner (FD) practicing for 30 years.

3.1. Quantitative analysis of the multiple-choice question

3.1.1. Sensitivity, specificity, accuracy

Out of the 684 answers collected by 19 examiners, 122 were TP, 394 TN, 62 FP and 106 FN. Table 1 shows the percentages of TP, FN, TN, FP by examiner. Sensitivity, or the capability to identify the correct matches, was obtained by the following formula TP/(TP + FN); specificity, or the capability to detect the incorrect AM radiographs, corresponded to the percentage of TN out of the total radiographs (TN + FP); accuracy was the estimation of the overall performance and corresponded to the percentage of the correct answers (TP + TN) out of the total answers (TP + FN + TN + FP). The