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# Forensic value of orthodontic records for human identification: a systematic review

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**ABSTRACT.** Extensive dental records are produced for orthodontic planning and treatment. Photographs, radiographs, and descriptive data used to register patient progress have benefited the fields of civil litigation and human identification. This study aimed to perform a systematic literature review guided by the following question: What type of orthodontic *antemortem* (AM) data have been used more often to confirm human dental identifications? The research protocol followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) and the Joanna Briggs Institute (JBI) manual. Registration was made in Open Science Framework. Ten databases were searched (LILACS, BBO, Cumed, Embase, MedLine [PubMed], SciELO, Scopus, Web of Science, Easy Dans, and BDTD). The eligible studies were only descriptive observational and should address the topic of human identification using orthodontic AM data. The risk of bias was assessed with the JBI tool. The initial search found 2,216 studies, of which 16 were eligible. Clinical photographs and panoramic radiographs were the most common orthodontic AM data. Most human identification cases relied on morphological (e.g., rotation and crown shape) and therapeutic (e.g., orthodontic appliances and restorations) identifiers. Orthodontic records can support human identification with relevant dental evidence, especially when providing images (radiographic or not). Forensic dentists should understand proper image analysis to interpret and detect morphological and therapeutic identifiers of forensic value.

**Keywords:** Anatomy;forensic dentistry; orthodontics; radiograph; dental records.

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## Introduction

Human identification relies primarily on the comparison between *antemortem* (AM) and *postmortem* (PM) data (Franco et al., 2013; Franco, Orestes, Coimbra, Thevissen, & Fernandes, 2019). The comparison is usually accomplished through fingerprint, dental, and genetic analyses (INTERPOL, 2018). Particularly in human dental identification, AM data consists of photographic, radiographic, and tomographic images, dental casts, and descriptive data entries (Franco et al., 2013; Angelakopoulos, Franco, Willems, Fieuws, & Thevissen, 2016). The obtained AM data is reproduced PM to provide a proper comparative process (Silva et al., 2016). Hence, AM radiographs will be compared to PM radiographs, preferably using the same image acquisition technique (Silva et al., 2016), and clinical photographs will be compared to autopsy photographs. After AM and PM data collection, dental charting is performed for a standardized comparison of dental features (Franco et al., 2019), which can be morphological, therapeutic, and pathological (Picoli et al., 2019). The comparative process occurs separately per tooth position and surface and can reveal similarities and discrepancies between AM and PM data (Senn & Weems, 2013). Consistent similarities and the lack of unexplained disparities in the reconciliation phase can confirm an identification (Senn & Weems, 2013).

Orthodontics requires a detailed assessment of patients' malocclusion and dentomaxillofacial status (Nanda & Kapila, 2009). In this context, the produced orthodontic data emerge to forensic odontology as a source of vast AM data (Silva et al., 2011). A recent systematic review showed the variety of dental records used for orthodontic diagnosis and treatment planning to the point of impossibility in defining a minimum data set that might benefit general dental practice (Rischen, Breuning, Bronkhorst, & Kuijpers-Jagtman, 2013). Specifically, orthodontists have traditional tools at their disposal, such as intra- and extraoral

radiographs and photographs, plaster casts, and wax bites, as well as more contemporary technology, namely intra- and extraoral facial scanning, cone-beam computed tomography, and magnetic resonance imaging (Rischen et al., 2013). Despite the recent advances in clinical devices, it is unclear whether forensic dentists understand the proper visualization and interpretation of AM data in their multiple forms. Although PM data collection evolved to enable high-tech practice in medicolegal institutions, the availability and quality of AM data will dictate the outcome of human dental identifications.

Understanding the case-specific characteristics of human dental identification studies reported in the scientific literature is crucial for investigating the actual value of orthodontic records in the forensic scenario, especially in forensic odontology. The present study aimed to perform a systematic literature review of descriptive observational studies reporting human dental identification using orthodontic records. The guiding question was: "What kind of orthodontic *antemortem* data have been used more often to confirm human dental identifications?"

## Material and methods

### Registration of the research protocol

A protocol was designed for this systematic review according to the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses – Protocols (PRISMA-P) (Moher et al., 2015). The study was registered in Open Science Framework (https://osf.io/3ptjs). The systematic review followed PRISMA (Page et al., 2021) guidelines and The Joanna Briggs Institute (JBI) manual (Aromataris & Munn, 2020).

### Research question and eligibility criteria

The following guiding research question was based on the PVO acronym (Population, Variable, and Outcome): What is the forensic value of orthodontic records for human identification?

The inclusion criteria consisted of descriptive observational studies (case reports and case series) reporting the process of human dental identification (O – outcome) of unknown bodies (P – population) using orthodontic data (V – variable). The exclusion criteria consisted of studies using dental records obtained for purposes other than orthodontic treatment, not describing the type of dental records, and using only descriptive material for human identification, such as written clinical files and dental charts. Additionally, editorials, letters to the editor, abstracts of scientific proceedings, books, and book chapters were excluded.

### Data sources

The LILACS, BBO, Cumed, Embase, MedLine (via PubMed), SciELO, Scopus, and Web of Science electronic databases were searched as primary study sources. The Easy Dans and BDTD platforms were searched to retrieve the grey literature. Initially, Medical Subject Headings (MeSH) and their synonyms were combined with the Boolean operators AND/OR to build a search string for MedLine. Subsequently, this search string was adapted to other databases, following their respective search engine and syntax (Table 1).

**Table 1.** Database-specific search strategies.

| Database | Search Strategy (December 2021) |
|---|---|
| Embase<br>https://www.embase.com | #1 = ((forensic dentistry) OR (forensic anthropology) OR (forensic sciences) OR (human identification))<br>#2 = ((orthodontics) OR (dental records) OR (documentation/standards) OR (orthodontic documentation))<br>#3 = #1 AND #2 |
| BVS (Virtual Health Library)<br>LILACS, BBO, Cumed<br>https://pesquisa.bvsalud.org/ | ((forensic dentistry) OR (forensic anthropology) OR (forensic sciences) OR (human identification)) AND ((orthodontics) OR (dental records) OR (documentation/standards) OR (orthodontic documentation)) AND (db:((LILACS) OR (BBO) OR (CUMED))) |
| PubMed<br>http://www.ncbi.nlm.nih.gov/pubmed | #1 = ((Forensic Dentistry)[Mesh] OR (Forensic Anthropology)[tw] OR (Forensic Sciences)[tw] OR (Human Identification)[tw])<br>#2 = ((Orthodontics)[Mesh] OR (Dental Records)[tw] OR (Documentation/standards)[tw] OR (Orthodontic Documentation)[tw])<br>#3 = #1 AND #2 |
| SciELO<br>http://www.scielo.org/ | ((Forensic Dentistry) OR (Forensic Anthropology) OR (Forensic Sciences) OR (Human Identification)) AND ((Orthodontics) OR (Dental Records) OR (Documentation/standards) OR (Orthodontic Documentation)) |

| | |
|---|---|
| Scopus<br>http://www.scopus.com/ | TITLE-ABS-KEY(((forensic dentistry) OR (forensic anthropology) OR (forensic sciences) OR (human identification)) AND ((orthodontics) OR (dental records) OR (documentation/standards) OR (orthodontic documentation))) |
| Web of Science<br>http://apps.webofknowledge.com/ | #1 TS=((Forensic Dentistry) OR (Forensic Anthropology) OR (Forensic Sciences) OR (Human identification))<br>#2 TS=((Dental Records) OR (Orthodontics) OR (Documentation/standards) OR (Orthodontic Documentation)))<br>#3 = #1 AND #2 |
| Grey Literature | |
| BDTD (Brazilian Digital Library of Theses and Dissertations)<br>https://bdtd.ibict.br/vufind/ | ((Forensic Dentistry) OR (Forensic Anthropology) OR (Forensic Sciences) OR (Human Identification)) AND ((Orthodontics) OR (Dental Records) OR (Documentation/standards) OR (Orthodontic Documentation)) |
| Easy Dans<br>http://www.easy.dans.knaw.nl/ | ((Forensic Dentistry) OR (Forensic Anthropology) OR (Forensic Sciences) OR (Human Identification)) AND ((Orthodontics) OR (Dental Records) OR (Documentation/standards) OR (Orthodontic Documentation)) |

Studies with restricted access to full texts were requested from the Bibliographic Commutation Program (COMUT) of the Brazilian Program of Information in Science and Technology (IBICT). If the full texts were not retrieved via COMUT, the corresponding authors were contacted by e-mail.

To ensure an extensive search, five specialists on the research topic were recruited and contacted via e-mail about potentially convenient articles for this systematic review based on the established eligibility criteria. Additionally, the reference lists of the eligible studies were searched for potential inclusions.

## Study selection

The studies retrieved from the databases were exported to EndNote Web™ (Thomson Reuters, Toronto, Canada) for the automated exclusion of duplicates and organization. The grey literature was recorded in Microsoft Word™ (Microsoft™ Ltd, Washington, USA) for manually removing duplicates.

The reviewers performed a calibration exercise before the selection process. They debated and applied (pairwise) the eligibility criteria to simulate the selection of 20% of studies. The formal selection process started after reproducibility reached $\geqslant 0.81$ with Kappa statistics.

The studies were then exported to Rayyan QCRI (Qatar Computing Research Institute, Doha, Qatar) for the title and abstract readings according to the eligibility criteria. Two reviewers (CDT and DTS) performed the analyses supervised by a third one (AF), who contributed in case of disagreements during the selection. Next, the full texts were read. In this phase, all excluded studies had their reasons for exclusions registered.

Translations were applied during study selection only if the text was published in languages other than English, Portuguese, and Spanish.

## Data collection

The first data block collected from the eligible studies consisted of sample characteristics regarding age group, sex distribution, and nationality. The next one included cadaver information, such as status and cause of death. The third and main data block referred to orthodontic records used for human dental identification, such as the time lapse between AM and PM records, the origin of orthodontic records (retrieved from the dental clinic or relatives/family members), the form of obtaining the exam, type of orthodontic record (AM), dental features considered during human identification, and type of PM data produced for comparisons. Consistency during this process was achieved by training the reviewers with 20% of the sample under the supervision of a third reviewer for data collection.

Studies with incomplete data justified the online request to the corresponding authors. E-mails were sent up to three times in seven days.

## Risk of bias

Two reviewers (DTS and CDP) independently assessed the risk of bias using the JBI Critical Appraisal Tool for descriptive study models, namely case reports and case series (Moola et al., 2020). Persistent disagreements between reviewers were solved by a third one (LRP), a specialist in the topic. Each study was categorized according to the number of affirmatives to the JBI questions. The risk of bias was high when positive answers were below 49%, moderate between 50% and 69%, and low when positive answers were above 70% (Franco et al., 2019).

### Synthesis of outcomes

The data were predominantly analyzed with descriptive assessments. Quantitative data, such as the time lapse between AM and PM data, were assessed with descriptive statistics of central tendency (mean) and dispersion (standard deviation), expressed in years.

## Results

### Study selection

The main electronic data search detected 1,938 studies, followed by 278 found in the grey literature (n = 2,216). After excluding duplicates, the sample decreased to 1,369 between the primary and grey literature. These studies underwent title and abstract readings. Sixty-nine studies remained for full-text analyses. Thirteen full texts were not found, and 56 were fully analyzed. Based on the eligibility criteria, 43 articles were excluded, and 13 eligible studies remained. The specialist on the topic added one study, and the reference lists of the eligible studies revealed two others. The final sample consisted of 16 eligible studies (Figure 1).

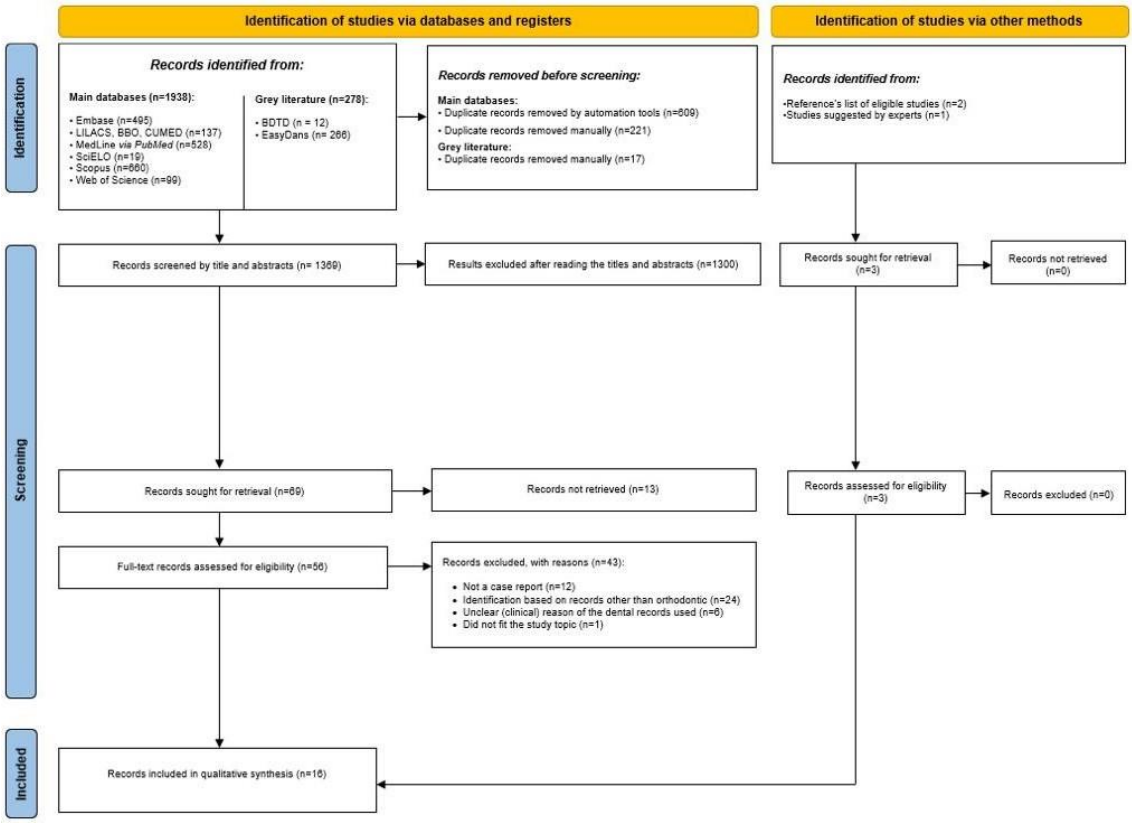


**Figure 1**. PRISMA flowchart of the selection process of studies included in the systematic review.

### Main characteristics of eligible studies

The studies were published between 2002 and 2021. Twelve articles (75%) were reported from Brazil (Paranhos, Caldas, Iwashita, Scanavini, & Daruge Júnior, 2008; Silva Daruge Júnior, Pereira, de Almeida, & de Oliveira, 2008; Caputo, Reis, Silveira, Guimarães, & Silva 2011; Da Silva, Chaves, Paranhos, Lenza, & Daruge Junior, 2011; Terada et al., 2014; Belotti et al., 2015; Argollo, Argollo de Argollo & Marques, 2017; Silva et al., 2017; Baldim, de Almeida, Delwing, & Tinoco, 2019; Freire, Bento, Rabello, & Santiago, 2019; Picoli et al., 2019; Correia et al., 2021), two (12.5%) from the USA (Goodman & Hilmmerberger, 2002; Lewis, Shiroma, Guenthner, & Dunn., 2004), and one (6.25%) from South Africa (Bernitz & Solomon, 2014). One study did not specify the origin of the case (Cardoza & Wood, 2015). Ten studies (62.5%) were published in English (Goodman & Hilmmerberger, 2002; Lewis et al., 2004; Caputo et al., 2011; Da Silva et al., 2011; Bernitz & Solomon, 2014; Terada et al., 2014; Cardoza & Wood, 2015; Silva et al., 2017; Picoli et al., 2019; Correia et al., 2021) and six (37.5%) in Portuguese (Paranhos et al., 2008; Silva et al., 2008; Belotti et al., 2015; Argollo et al., 2017; Baldin et al., 2019; Freire et al., 2019). There was no mention of guidelines for structuring case

reports, such as Case Report Guidelines (CARE). Two studies described ethical aspects (Bernitz & Solomon, 2014; Picoli et al., 2019). Thirteen articles reported each a single case of human identification using orthodontic records, one showed a series of five cases (one eligible case within) (Cardoza & Wood, 2015), one described a mass disaster case (one eligible case within) (Lewis et al., 2004), and one reported two cases (one eligible case within) (Belotti et al., 2015) (Table 2).

**Table 2**. Main characteristics of the eligible studies.

| Author and year | Country | Age | Sex | Cadaver status | Cause/condition of death |
|---|---|---|---|---|---|
| Goodman & Hilmmerberger, 2002 | USA | Between 14-15 years | ♀ | Skeletal remains | Homicide |
| Lewis et al., 2004 | USA | 17 years | ♂ | n/r | Drowning |
| Paranhos et al., 2008 | Brazil | n/r | n/r | Charred | Car fire |
| Silva et al., 2008 | Brazil | Adult | ♂ | Charred | n/r |
| Caputo et al., 2011 | Brazil | Adult | n/r | Charred | Car crash (accident) |
| Da Siva et al., 2011 | Brazil | Adult | ♂ | Charred | n/r |
| Bernitz & Solomon, 2014 | South Africa | 19 years | ♂ | Charred | Homicide |
| Terada et al., 2014 | Brazil | Between 19-26 years | ♂ | Skeletal remains | Firearm injury |
| Belotti et al., 2015 | Brazil | n/r | ♂ | Charred | Car crash (accident) |
| Cardoza & Wood, 2015 | n/r | n/r | n/r | Charred | Car crash (accident) |
| Silva et al., 2017 | Brazil | 32 years | n/r | Partially skeletonized | Cranial-encephalic trauma (firearm) |
| Argollo et al., 2017 | Brazil | 17 years | ♀ | Charred | n/r |
| Baldin et al., 2019 | Brazil | Adult | ♂ | Putrified | Drowning |
| Freire et al., 2019 | Brazil | Adult | ♂ | Putrified | n/r |
| Picoli et al., 2019 | Brazil | 21 years | ♂ | Putrified | n/r |
| Correia et al., 2021 | Brazil | 38 years | ♂ | Putrified | Homicide |

♂: male; ♀: female; n/r: not reported; n.c.: not clear – the study reports the identification of a victim moving between London and Cape Town.

## Risk of bias

Two studies had a moderate risk of bias (Lewis et al., 2004; Paranhos et al., 2008), and 14 had a low risk of bias. The JBI question #5 was not applicable because it is designed for clinical case reports. Similarly, questions #6 and 7 were invalid because they investigate the effects of clinical interventions (Table 3).

**Table 3**. Risk of bias and methodological quality assessed with the Joanna Briggs Institute Critical Appraisal tool.

| Authors | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | % Yes | Risk of bias |
|---|---|---|---|---|---|---|---|---|---|---|
| Goodman & Hilmmerberger, 2002 | √ | √ | √ | √ | NA | NA | NA | √ | 100% | Low |
| Lewis et al., 2004 | √ | U | U | √ | NA | NA | NA | √ | 60% | Moderate |
| Paranhos et al., 2008 | U | U | √ | √ | NA | NA | NA | √ | 60% | Moderate |
| Silva et al., 2008 | √ | U | √ | √ | NA | NA | NA | √ | 80% | Low |
| Caputo et al., 2011 | √ | U | √ | √ | NA | NA | NA | √ | 80% | Low |
| Da Silva et al., 2011 | √ | √ | √ | √ | NA | NA | NA | √ | 100% | Low |
| Bernitz & Solomon, 2014 | √ | √ | √ | √ | NA | NA | NA | √ | 100% | Low |
| Terada et al, 2014 | √ | U | √ | √ | NA | NA | NA | √ | 80% | Low |
| Belotti et al., 2015 | √ | √ | √ | √ | NA | NA | NA | √ | 100% | Low |
| Cardoza &Wood, 2015 | U | √ | √ | √ | NA | NA | NA | √ | 80% | Low |
| Argollo et al., 2017 | √ | √ | √ | √ | NA | NA | NA | √ | 100% | Low |
| Silva et al., 2017 | √ | U | √ | √ | NA | NA | NA | √ | 80% | Low |
| Baldin et al., 2019 | √ | √ | √ | √ | NA | NA | NA | √ | 100% | Low |
| Freire et al., 2019 | √ | U | √ | √ | NA | NA | NA | √ | 80% | Low |
| Picoli et al., 2019 | √ | √ | √ | √ | NA | NA | NA | √ | 100% | Low |
| Correia et al., 2021 | √ | √ | √ | √ | NA | NA | NA | √ | 100% | Low |

√: yes; --: no; NA: not applicable; U: unclear. Q1: Were the demographic characteristics of patients (victim/cadaver) clearly described? Q2: Was patient (victim/cadaver) history clearly described and presented as a timeline? Q3: Was the current clinical (cadaveric) condition of patients (victim/cadaver) clearly described? Q4: Were diagnostic tests or assessment methods and the results clearly described? Q5: Was (Were) the intervention(s) or treatment procedure(s) clearly described? Q6: Was the post-intervention clinical condition clearly described? Q7: Were adverse (harm) or unanticipated events identified and described? Q8: Does the case report provide a key message?

## Main results of eligible studies

Half the victims who underwent dental autopsy were charred (50%) or putrefied or skeletonized (37.5%). The male sex prevailed (62.5%). The age of victims was between 14 and 38 years. The mean time lapse between AM and PM records was 4.41 ± 2.41 years, but 50% of studies did not have this information. All cases showed confirmed identifications. Dentists collected orthodontic data (AM data) in 50% of cases, and family members

in 12.5%. Six cases did not report the source of AM records, and in four (25%), the orthodontic records included intra- and extraoral photographs, panoramic and lateral cephalometric radiographs, and dental casts. Panoramic radiographs were the most used AM data, reported in 13 cases (81.25%). Identifications were confirmed by several means, including quantitative and qualitative comparisons between AM and PM records, manual or computerized, and even image superimposition. Morphological identifiers were more frequent in the identification process, followed by therapeutic identifiers. The most common PM data was intraoral photographs, followed by intraoral radiographs (Table 4).

**Table 4**. Dental data used for human identification and technical aspects of eligible studies.

| Authors, year | Time between AM-PM data | AM data holder | Data provider | Orthodontic phase of AM data | Type (items) of AM data | Type (items) of PM data | Main features considered during the identification process |
|---|---|---|---|---|---|---|---|
| Goodman & Hilmmerberger, 2002 | 6 years | Victim's dentist | n/r | Initial orthodontic records | Panoramic radiographs, lateral cephalometric radiographs, and dental casts | Periapical radiographs, photographs, lateral cephalometric radiographs, and dental casts | Morphological features<br>Mesiodistal crown width.<br>Tooth wear on the palatal surface of anterior maxillary teeth.<br>Distinctive anatomy of the buccal cusps of molars and premolars.<br>Supernumerary cusp of the maxillary left premolar.<br>Shape of teeth #36, 43, 44, and 46. |
| Lewis et al., 2004 | n/r | n/r | n/r | n/r | n/r | n/r | Morphological features<br>Missing first premolars.<br>Therapeutic features<br>History of orthodontic treatment. |
| Paranhos et al., 2008 | n/r | Victim's dentist | Victim's dentist | Initial orthodontic records | Intra- and extraoral photographs, treatment progress records, panoramic radiographs (with radiologic reports), lateral cephalometric radiographs with orthodontic analyses, and dental casts | Photographs and periapical radiographs | Morphological features<br>Root curvature of tooth #48<br>Therapeutic features<br>Occlusal composite restoration in tooth #16.<br>Metal restoration in teeth #17, 27, 46, and 47.<br>Fixed orthodontic appliances. |
| Silva et al., 2008 | 7 years | Victim's dentist | Victim's family | Initial orthodontic | Treatment progress | Periapical radiographs, | Morphological features |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | records | records, panoramic radiographs, bitewing, and periapical radiographs. | bitewings, and photographs | Anatomy and position of the maxillary left permanent teeth. Missing tooth #28. Therapeutic features Restorations in amalgam in teeth #16 and 46. |
| Caputo et al., 2011 | n/r | n/r | n/r | Initial orthodontic records | Intra- and extraoral photographs, orthodontic treatment planning, lateral cephalometric radiographs, panoramic radiographs, periapical radiographs, records of planned extractions, dental records, and wax bites | Radiographs and photographs | Morphological features Root and root canal shapes in tooth #12. Therapeutic features Restoration in amalgam in tooth #12. Fractured restoration in amalgam in tooth #16. Fixed orthodontic appliances. |
| Da Siva et al., 2011 | 1 year | Victim's dentist | Victim's family | Initial orthodontic records | Treatment progress records, panoramic radiographs, lateral cephalometric radiographs, intra- and extraoral photographs, dental casts, records of planned extractions for supernumerary teeth, and a radiology clinic report | Periapical radiographs and photographs | Morphological features Supernumerary between teeth #15 and 16, 25 and 26, 34 and 35, and 44 and 45; Therapeutic features Shape and position of amalgam restorations in posterior teeth. Fixed orthodontic appliance. |
| Bernitz & Solomon, 2014 | n/r | Victim's dentist | n/r | Final orthodontic records | Panoramic radiographs | Periapical radiographs and photographs | Morphological features Missing teeth #15 and 25 Root angulations of teeth #14 and 24 Maxillary sinus shape Therapeutic features Restorative material in teeth #17, 16, 26, 27, 37, 36, 45, 46, and 47. |
| Terada et al., | n/r | Victims' | Victim's | Initial | Extraoral | Periapical | Morphological |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2014 | | family | family | orthodontic records | photographs, panoramic radiographs, and dental casts | radiographs and intra- and extraoral photographs | radiographs<br>Supernumerary on the lingual aspect of teeth #32 and 33.<br>Rotation of tooth #34.<br>Missing teeth #36, 38, 46, and 47<br>Marked tooth loss (decay) of tooth #18.<br>Therapeutic features<br>Crown, post, and partial root canal obturation of tooth #11.<br>Orthodontic appliances |
| Belotti et al., 2015 | 5 years | n/r | Victim's family | n/r | Intra- and extraoral photographs and maxillary dental casts | Intra- and extraoral photographs | Morphological features<br>Distance between maxillary third molars.<br>Shape of teeth #18 and 28. |
| Cardoza &Wood, 2015 | n/r | Victim's dentist | Victim's dentist | Initial orthodontic records | Dental casts | Dental casts | Morphological features<br>Palatal rugae. |
| Silva et al., 2017 | 7 months | n/r | n/r | Intermediate orthodontic records | Intraoral photographs and a panoramic radiograph | Intra- and extraoral photographs | Therapeutic features<br>Fixed orthodontic appliances (brackets and bands) between first molars.<br>Occlusal amalgam restorations in teeth #36 and 46.<br>Rotation of premolars and diastemas of anterior maxillary teeth. |
| Argollo et al, 2017 | 4 years | Victim's dentist | Victim's family | Initial orthodontic records | Panoramic radiographs, two periapical radiographs (anterior teeth), dental casts, intra- and extraoral radiographs, and clinical progress records. | Intra- and extraoral photographs | Morphological features<br>Crown shape of remaining teeth.<br>Missing teeth #14, 24, 34, and 44.<br>Developmental stage of third molars.<br>Supporting data: shape of the palatal rugae.<br>Therapeutic features<br>Restorative composite |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | material in teeth #16, 26, and 46. Fixed orthodontic appliances. Endodontic obturation material in tooth #36. Morphological features Shape of the incisal edges of teeth #11 and 21. Crown bulge in tooth #43. Diastemas and rotation. Therapeutic features Restorative composite material in teeth # 16, 15, 36, 37, 46, and 47. Missing tooth #28. Fixed orthodontic appliances. |
| Baldin et al., 2019 | <1 year | n/r | Victim's family | Initial orthodontic records | Intra- and extraoral photographs, panoramic radiographs, and lateral cephalometric radiographs (and analyses) | Periapical radiographs, lateral cephalometric radiographs, and dental casts | Morphological features Midline diastema between teeth #31 and 41. Missing teeth #36 and 46. Therapeutic features Fixed orthodontic appliances in teeth #15 and 25. Pathological features Occlusal caries/decay in teeth #47. |
| Freire et al, 2019 | (recent) | Victim's dentist | Victim's family | Initial orthodontic records | Lateral cephalometric radiographs (and analyses), panoramic radiographs, and intra- and extraoral photographs. | n/r | Morphological features Roots shape in first and second mandibular molars. Cingulum prominence of maxillary anterior teeth. Therapeutic features Fixed orthodontic appliances in all permanent teeth, except for third molars. |
| Picoli et al., 2019 | 6 years | Victims' family | Victim's family | Intermediate (during) orthodontic records | Intra- and extraoral photographs, and panoramic radiographs | Photographs and periapical radiographs | |
| Correia et al., | 6 years | n/r | Victim's | Initial | Intraoral | Photographs | Therapeutic |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2021, | family | orthodontic records | photographs, panoramic radiographs, and left/right bitewing radiographs | and periapical and bitewing radiographs | features Restorative composite material in teeth #18, 17, 16, 27, 28, 38, 37, 47, and 48. Endodontic obturation in tooth #36. Endodontic obturation and prosthetic material in tooth #46. Pathological features Occlusal-distal caries/decay in tooth #24. Cervical caries/decay in teeth #34 and 35. |

n/r: not reported; #: International Dental Federation.

## Discussion

Dental human identification is especially relevant when fingerprint analysis is not feasible, such as in charred and mutilated bodies and skeletal remains (Silva et al., 2015). Almost 94% of the cases screened in the present study included charred or skeletonized victims. Orthodontic records provide forensic dentists with extensive *antemortem* (AM) data that may favor human identification. This study aimed to review human dental identification cases that benefited from orthodontic records for confirmation. The rationale was to expose the most common AM orthodontic records and their contribution to human identification.

The first extracted data block showed an interesting outcome regarding the country of origin of the reported cases. Brazil held 75% of human dental identification cases found in this review. The national legal and ethical standards for clinical record keeping may have contributed to the positive cases in Brazil. According to the Brazilian Code of Dental Ethics, producing and storing dental records are mandatory in clinical practice. According to Federal Law n. 13.787/18, the minimum storage time for medical-related records is 20 years. Although this Law was published in 2018, some cases (published before 2018) were eventually supported by Resolution 091/09 of the Brazilian Federal Council of Dentistry, which had set the storage of paper-based (physical) records and the permanent storage of digital data to ten years. Other pertinent standards are implicit in the Brazilian Consumer Code. The progressive development of national standards contributes to forensic practice by improving AM data availability.

Delays in gathering AM records postpone the reconciliation process directly. For instance, one of the cases (Cardoza & Wood, 2015) reported a victim who traveled to Mexico for an orthodontist appointment. Hence, AM orthodontic records usually produced, such as photographs and radiographs, should be promptly available. However, the orthodontist did not make any radiographic records. A questionnaire-based survey with 142 Swedish orthodontists revealed that most (99%) frequently use panoramic radiographs (Stervik, Lith, Westerlund, & Ekestubbe, 2021). The present review confirms the previous literature by showing that panoramic radiographs were the most shared AM data (81.25%) throughout the case reports. Screening patients for existing bone lesions is a reason behind the motivation for taking preliminary panoramic radiographs in orthodontics. Starting treatments without radiographic planning might neglect existing adverse conditions. In this study, at least 11 cases used initial orthodontic records, highlighting the relevance of properly documenting patient status before treatment. Forensic dentists must understand the correct interpretation of panoramic radiographs to detect dental features of utmost interest for human identification.

Among the dental features of interest for human identification, pathological ones were less usual. Conversely, morphological and therapeutic features were described frequently. Crown shape and root angles were mentioned among morphological features, and the most noticeable therapeutic features were restorations (metal or composite). Studies have wisely claimed that combining restored, missing, and

unrestored teeth would lead to a rare enough differentiation level to contribute significantly to human identification (Adams, 2003a; Adams, 2003b). Restorations can be explored from a deeper perspective by describing the restorative material, restoreddental surfaces, and restoration shape in the prepared cavity. Odontosearch (USA) and KMD PlassData DVI (KMD, Copenhagen, Denmark) are current software examples with forensic applications that analyze the presence/frequency of dental restorations and restorative material, respectively.

AM photographs might be essential for a clearer understanding of the registered restorative materials. To a certain extent, metallic and non-metallic materials may not be clearly distinguished in radiographs depending on the image acquisition protocol and storage conditions. At least 12 cases in this literature review mentioned photographic data. These data are usual in orthodontics mainly because treatment planning and monitoring can be accomplished with or benefit from visually assessing patient conditions. The non-exposure to ionizing radiation and the more practical image acquisition technique compared to radiographs stand out among the advantages of photographic records. Authors (Angelakopoulos et al., 2017) have demonstrated that dental features (identifiers) detected in intraoral photographs can be highly distinctive for human identification. More specifically, tooth rotation is considered a clinically detectable morphological feature highly relevant to identify individuals (Angelakopoulos et al., 2017). Rotation is optimally registered with photographs, which were mentioned in three articles in our study, especially regarding anterior teeth and premolars. Intraoral images can also detail other features, such as orthodontic appliances, usually represented by brackets, bands, and wires. Considering this study addressed the use of orthodontic records for human identification, it is expected that orthodontic appliances would be routine among therapeutic features in the reconciliation process.

It is worth noting that rotation and orthodontic appliances are not necessarily consistent features during orthodontic treatments, meaning that rotation, for instance, is usual in early treatment stages. Consequently, AM and PM (*postmortem*) data with a broad time lapse may cause (explainable) discrepancies, such as a charted tooth with rotation AM and sound PM. The same applies to orthodontic appliances, which can be installed, removed, changed, and reinstalled during treatment. In this study, eight case reports mentioned the time between AM and PM data. According to these cases, the mean time was nearly 4.5 years, corroborating the possibility of several changes between AM and PM charting. Forensic dentists must be aware of occasional dental status changes during orthodontic treatment and progressive decay that can affect this status and generate explainable discrepancies.

This study is not free of limitations. The main one is only considering case report studies/case series. The lack of analytical observational studies allowed only a general mapping of available publications. Hence, our findings were solely based on descriptive studies. New retrospective analyses reviewing forensic records are encouraged to increase the evidence of cases that used orthodontic records for human identification.

This study highlighted the importance of orthodontic records for human identification and showed the most frequent orthodontic treatment data. In parallel, it emphasized the importance of dental record-keeping to cooperate with the justice system whenever needed. Clinical dentists must understand their role in the human identification process as providers of valuable data. Forensic dentists, however, must be able to interpret and explore the available data to assess dental features optimally during the reconciliation process.

## Conclusion

The present review compiled case-specific characteristics of human dental identification studies relying on orthodontic records. The most common data were intraoral photographs and panoramic radiographs, and the most used dental features (identifiers) were morphological (such as rotation of anterior teeth and premolars and crown shape) and therapeutic (such as orthodontic appliances - brackets and bands - and restorations) ones. Forensic dentists must understand these characteristics to correctly interpret and optimally explore orthodontic AM records during human dental identification.

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