Dental Radiographic Superimposition: An exciting addition to the Forensic Odontology armamentarium

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Highlights

- Forensic odontology plays an important role in the identification of severely decomposed or carbonised corpses.
- Forensic odontologists were consulted for the identification of a severely carbonised corpse with extensive dental restorative work.
- Superimposition of ante- and post-mortem dental radiographs were utilised in the positive identification process.

Abstract

Forensic odontology plays an important role in the identification of severely decomposed or carbonised corpses, particularly when conventional identification methods fail. This case report highlights the use of dental radiographic superimposition of extensive dental restorative work in the identification of a severely carbonised corpse. Ante- and post-mortem radiographs were analysed via superimposition using the Adobe Photoshop® 2021 image manipulation software. Multiple concordant features, as well as near-perfect radiographic superimposition, enabled a positive identification of the carbonised corpse. This emphasises the need for consultation of forensic odontologists in cases where dental restorative work is noted during post-mortem examination.

Keywords: Forensic odontology, victim identification, radiographic superimposition

1. Introduction

Forensic odontology or more simply, forensic dentistry, is a specialised field in forensic science that utilises teeth and surrounding structures in the identification of human remains [1]. The high mineral content of teeth and the presence of robust restorative materials enable the dentition to survive inhumation well. Forensic odontology plays an important role in the identification of severely decomposed or carbonised corpses, where conventional identification methods such as fingerprints and DNA analysis may fail.

Dental features, anomalies, relationships or restorative work can all be used for victim identification. Forensic odontology analyses the concordant features between various ante- and post-mortem records including dental records, dental casts, photographs and radiographs [1], [2], [3]. When ante-mortem records are not available, the dentition and skull features may also be used for gender and ethnicity profiling as well as age estimation from the teeth. The extensive number of analytical features used in dental identification highlights the complexity of this field and the need for highly-trained individuals to perform these analyses [1,4]. After dental post-mortem analysis certain conclusions can be drawn, including positive identification, possible identification, insufficient evidence and exclusion. There are no minimum number of concordant dental features required for victim identification and, in certain instances, even a single tooth with unique features may be adequate for identification [5].

General dental procedures, including restorations and crowns and bridges, are individually fabricated for each patient and are therefore considered unique to that individual. The majority of dental restorations are composed of either dental amalgam or composite materials placed in a uniquely prepared cavity following dental decay removal. Dental crowns and bridges are fabricated extraorally from a variety of materials that, in most instances, cover the entire crown of a tooth. Dental implants are becoming popular for the replacement of missing teeth and consist of three major components, the screw placed inside the jawbone (substructure), the crown or bridge (superstructure), and an abutment that connects the two. In some instances, the substructure and abutment may be fused.

Advancements in radiographic imaging allow for the development of new applications, not only in clinical scenarios, but also in the field of forensic odontology. This includes the utilisation of radiographic examinations for post-mortem imaging as an adjunct in forensic investigations [4,[6], [7], [8]]. Superimposition techniques utilising ante- and post-mortem records in forensic identification have been used in various forms. These include post-mortem dental casts, three-dimensional (3D) scanned skulls and computerised tomography (CT)-aided 3D printed models superimposed over ante-mortem photographs [2,7,[9], [10], [11], [12], [13], [14]]. Additionally, ante-mortem radiographs of surgical plates and screws used in the extremities may be superimposed on post-mortem radiographs [9]. Finally, visual aids generated from comparative ante- and post-mortem radiographs may aid in the comprehension of expert evidence by medical laymen [6].

The purpose of this case report is to highlight the use of dental radiographic superimposition in the identification of severely decomposed or carbonised individuals.

2. Case description

The details of this case have been purposely omitted in order to maintain anonymity. The case has also been finalised before a court of law and is therefore no longer sub judice.

The Forensic Odontology unit at the University of Pretoria was requested to assist with the identification of a severely carbonised corpse. The corpse was taken to a nearby mortuary with no on-site forensic odontology services. During the examination, the forensic pathologist observed extensive dental restorative work in the form of fixed prosthodontics (dental bridges). The dental superstructures, together with the poorly integrated dental implants, were extracted from the mandible and maxilla. This dental evidence, together with the obtained ante-mortem radiograph from the dentist of the suspected individual, were submitted to the Forensic Odontology unit for analysis. No information was provided from the dentist regarding the type or identification code of the dental implants.

Three individual bridges were received (Fig. 1), the first of which consisted of six porcelain-fused-to-metal (PFM) crowns. The second bridge consisted of five PFM crowns with one retained implant screw. The third bridge consisted of nine PFM crowns. The ante-mortem records consisted of a panoramic radiograph showing implant-retained bridges in all four quadrants of the mandible and maxilla (Fig. 2). This alluded to the fact that additional evidence, in the form of fixed prosthodontics, possibly remained in situ in the carbonised corpse. A Lodox scan of the intact jawbones was requested in order to assess the remaining implants (Fig. 3). The Lodox scan is a high-speed imaging system with low radiation emission that was derived from technology originally created for the mining security sector in South Africa [15]. After assessing the images from the scan, it was clear that a significant amount of dental work remained in situ that could have been utilised for comparative assessment. Radiographic examinations were performed on the submitted dental superstructures and single implant screw with the abutment to gather information that could assist in victim identification (Fig. 4).

Figure 1: Submitted dental superstructures and single dental implant extracted from the corpse.

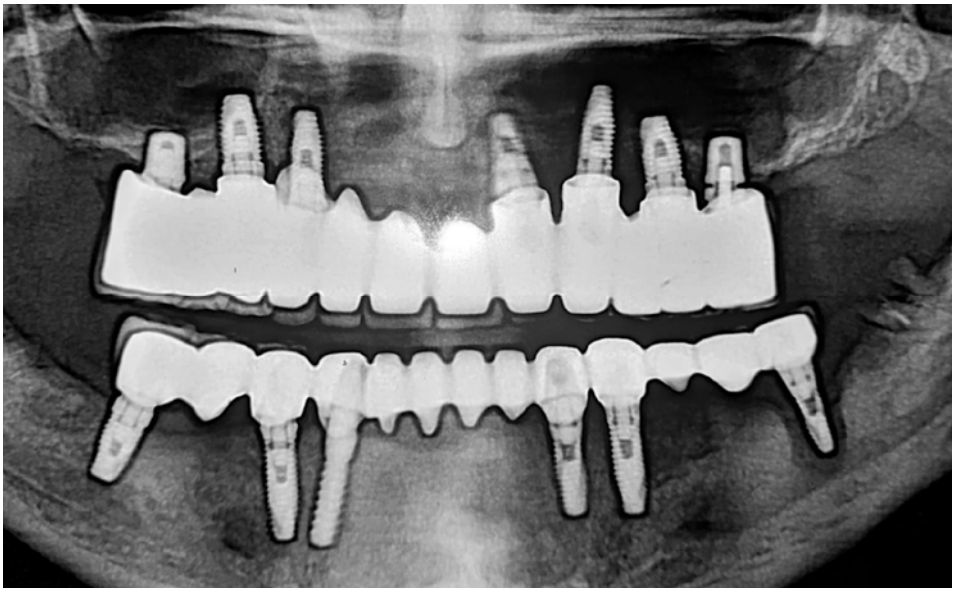

Figure 2: Ante-mortem panoramic radiograph of the suspected victim showing numerous dental implants in the maxilla and mandible with implant-supported bridges.

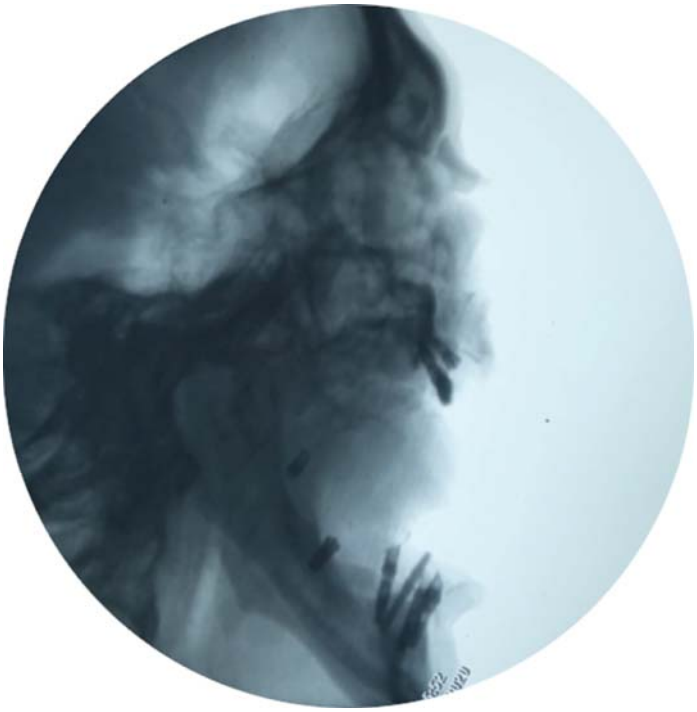

Figure 3: Lodox scan of the victim after the some of the dental superstructures were extracted. The imaging shows retained maxillary and mandibular dental implants.

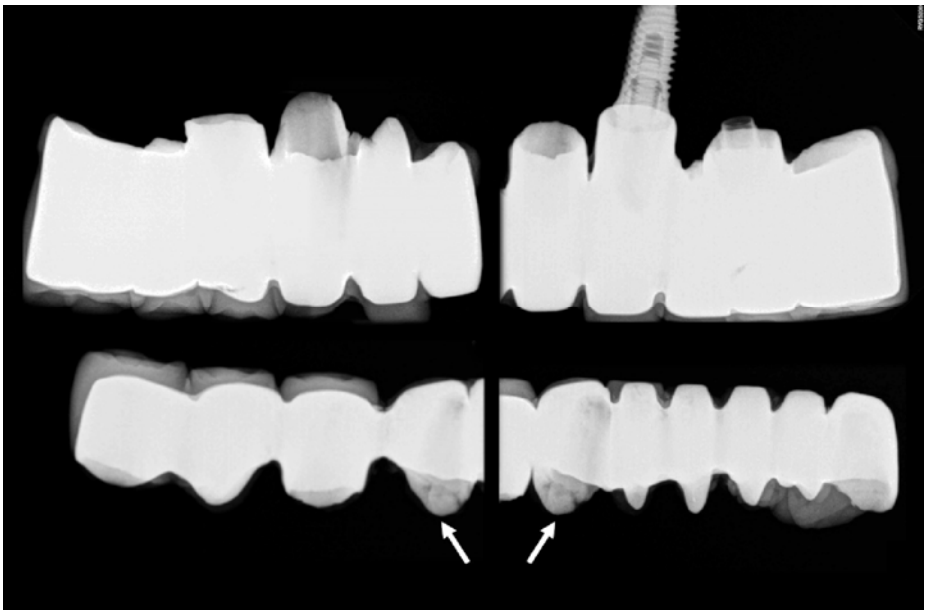

Figure 4: Radiographic imaging of the submitted evidence. Due to the limitations in size of digital radiographic sensor, the mandibular bridge required two separate acquisitions with overlap in the right canine region (arrows).

The ante- and post-mortem radiographs were analysed via superimposition using the Adobe Photoshop® 2021 image manipulation program (Copyright © 2021 Adobe). The first step in the superimposition process involved changing the opacity of the post-mortem images in order to increase transparency. The colour of modified images was set to blue for improved visualisation of areas of correspondence. The images were then transferred onto the ante-mortem records (Fig. 5A). Adjustments in size were made to correct for magnification differences between the radiographic examinations. Finally, minor changes in angulations were made and the post-mortem records were then superimposed over the ante-mortem radiograph (Fig. 5B). It is important to note that small changes in the angulation of the structures for superimposition do not alter the surface characteristics and relationships used for comparison (Fig. 6). Two forensic odontologists worked together with a maxillofacial radiologist to analyse the corresponding features.

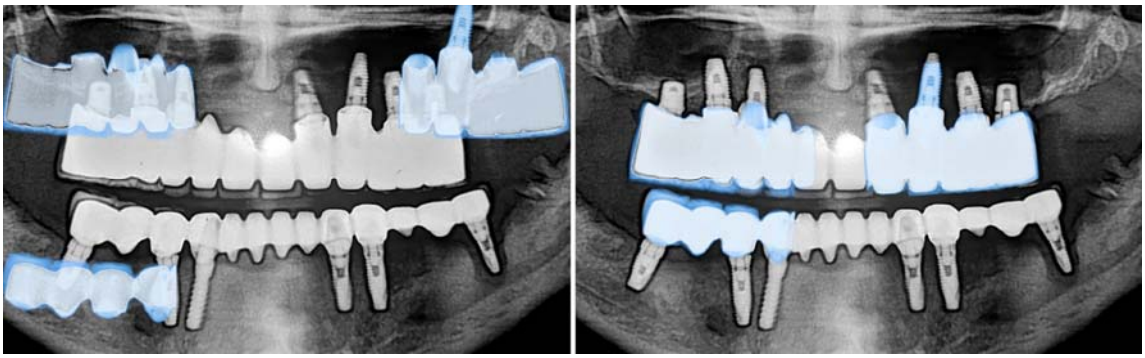

Figure 5: A. Transparent post-mortem radiographic images (blue) superimposed on the ante-mortem panoramic radiograph. **B.** Minor corrections for size and angulation resulted in a near perfect superimposition of the ante- and post-mortem radiographs.

Figure 6: Simulated image showing that minor changes in spacial orientation do not alter characteristics used in the subsequent comparative analysis.

The following concordant features were noted between the ante-mortem and post-mortem records:

1. The lack of teeth paired with the extent of fixed prosthodontic work on the Lodox post-mortem scan corresponded to ante-mortem records;
2. The unique shape of the crowns of the implant-supported bridges were highly characteristic;
3. The elongated and thinner metal flange of the PFM crown on the implant in the right maxillary canine region was visible on the submitted structures;
4. The angulation, abutment and implant features visible on the implant in the left maxillary canine area were highly characteristic.

These key concordant features, as well as the near-perfect radiographic superimposition, and the absence of any unexplained discrepancies, enabled the examiners to positively identify the carbonised corpse with the ante-mortem records provided.

3. Discussion

In South Africa, a country with high rates of violent crimes, there are substantial numbers of victims that require identification [11]. The advent of DNA profiling, which is considered a reliable and efficient means of victim identification, has partially aided in this identification process. DNA identification does however have its negatives, being expensive, technologically demanding, and logistically difficult to implement on a large scale [3]. This supports the need for fast, accurate and inexpensive methods of victim identification.

In forensic anthropology, craniofacial superimposition (CFS) involves comparing anatomical features of a skull with ante-mortem photographs [16,17]. This method has been used in the past when recovered skeletal remains, in the form of a skull, are thought to relate to a particular missing person, for whom photographs are available [16]. Methods of CFS have evolved enormously since their inception, particularly with the use of modern computer-based technology [17]. A 2015 review by Ubelaker analysed forensic cases reported during the period 1978 – 2009. The results found that of the 848 cases during that period, only 14 cases (1.7%) involved photographic superimposition. Furthermore, a steady decline in photographic superimposition was noted, likely due to the increased availability of DNA technology [16,17]. More recently, the New Methodologies and Protocols of Forensic Identification by Craniofacial Superimposition (MEPROCS) project developed a document recommending best practices and assessment criteria for CFS [18]. This framework aimed to serve as an international standard for avoiding particular assumptions that could bias the final analysis. Skull superimpositions on ante-mortem photographs have shown a high degree of accuracy, especially when using combined morphological and anatomical landmark techniques [11]. However despite these advanced techniques, a high degree of false-positive results still occur [11]. This could be explained by matching bony landmarks of post-mortem skulls to soft tissue profiles on ante-mortem photographs.

In forensic odontology, superimposition of ante- and post-mortem records, whether photographs, radiographs or other forms of dental records, were found to be more reliable than visual comparison alone [10,19]. The use of superimposed ante-mortem and post-mortem radiographs is a technique that has been used successfully for identification purposes in forensic anthropology. A 2016 study by Fujimoto et al. [13] used landmarks on tooth sockets to successfully identify individuals. These superimposed radiographs are particularly useful when areas of interest are small or difficult to visualise with conventional methods [4,20,21]. Unfortunately, limitations around spacial orientation and magnification differences may occur between ante- and post-mortem radiographs [22]. Care should be taken to ensure the orientation and angulation of the records being superimposed are near-identical [2]. However, in many cases, replicating the spacial orientation and exact angulation of post-mortem radiographs for comparison with ante-mortem radiographs is virtually impossible. In these instances, forensic odontologists may use a certain degree of expert judgment in analysing available records [11].

Additionally, computer-aided video superimposition devices do exist and may aid in the comparative process [20]. When photographing a post-mortem dental cast for comparison with ante-mortem photographs, the cast can be mounted on a rotational stand whereby angulations can be adjusted to resemble the ante-mortem image [2]. Alternatively, angulation and distortion limitations can be addressed if the cast is digitised or 3D scanned. This allows for adjustments in three dimensions with a high degree of reliability prior to superimposition on available ante-mortem records [10]. More recently, post-mortem computed tomography (PMCT) has been used successfully in victim identification. This imaging modality partially resolves the issues around spacial orientation, as this method allows for image reformatting and subsequent comparison with any type of radiograph. These PMCT images may be acquired in a non-invasive fashion, reducing the need for extensive corpse manipulation. Additionally, PMCT images provide detailed anatomical and pathological information not only of the teeth, but also the surrounding structures. Limitations include significant streak artifacts from metallic dental restorations and adjustment of the slice thickness to view the entire thickness of the tooth/teeth for accurate comparison [4,7,21].

Medical implanted orthopaedic devices usually have an engraved identification code and have been used successfully in the forensic identification process [23,24]. Dental implants are frequently used in the prosthodontic replacement of missing teeth and are therefore important adjuncts for use in forensic dental identification methods. Moreover, the majority of implants are made from titanium, a material with high resistance to degradation or damage [23,25]. The identification of implant manufacturers as a possible tool for victim identification has recently been streamlined through the utilisation of online software programs [26]. This is particularly useful in cases with adequate ante-mortem records containing implant manufacturers/serial numbers, pointing to the importance of adequate record-keeping in dentistry. Given these advances, the identification success of an implant manufacturer using manual or software-assisted methods still remains poor [3,22]. This is possibly due to the myriad of implant manufacturers currently available, often with different substructure designs. Additionally, the overlap in design features caused by the incorporation of successful features from other companies further complicates implant identification. Various unique features of dental implants can be used for forensic correlations, including the implant shape, surface characteristics such as grooves, and abutment design [3,22,[27], [28], [29]]. This analysis however remains a lengthy and complicated process [29]. Instead of focusing on identifying the implant manufacturer, concordant features between ante- and post-mortem radiographic records can be utilised in forensic cases, as illustrated in the current case report. This principle is based on the fact the once integrated in bone, dental implants do not modify their position or relationship with surrounding anatomic structures [23]. De Angelis and Cattaneo described a rare case whereby superimposition of ante- and post-mortem radiographs of dental implants were used successfully in the identification process [23].

With the advances in imaging, scanning and radiology, methods of analysis are becoming endless with imaging becoming a crucial component of forensic analysis [30]. The positional statement by the International Society of Forensic Radiology and Imaging states that "imaging is in the unique position to be able to address some of the subjectivity concerns with certain forensic anthropological methods by quantifying scaled or even non-metric methods" [30]. An effective way to assess the concordance of superimposed structures is to assign a numerical value to the level of correspondence of each surface. The overall percentage can be calculated and the two comparative records categorised as high probability, probability, comparability, insufficient evidence or exclusion [2].

4. Conclusion

The advancements of forensic science and radiology creates ideal circumstances for the bridging of these two modalities [6]. Post-mortem imaging is considered a new radiological subspecialty with more research required to establish accurate guiding protocols [31]. This method remains a rapid, inexpensive and easily attainable method for the identification of decomposed/carbonised bodies. Superimposition of ante- and post-mortem radiographs may be a useful adjunct in victim identification. A limitation of the current report is that most of the dental implants and superstructures were removed from the corpse during the post-mortem examination. If left in situ, additional features for correlation could have been used in the analysis, which may have further strengthened the overall evidence. This emphasises the need for consultation of forensic odontologists in cases where dental restorative work is noted during post-mortem examination. Additionally, no information was provided from the dentist of the suspected individual regarding the type or identification code of the dental implants. This would have facilitated rapid victim identification and again points to the importance of adequate record-keeping.

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Ethics

The study was conducted following approval by the Faculty of Health Sciences Research Ethics Committee, University of Pretoria (626/2021). All procedures followed were 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. This article does not contain any studies with animal subjects performed by any of the authors.

Declaration of Competing Interest

All authors have indicated that they have no potential conflicts of interest and no financial relationships relevant to this article to disclose.

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