

Potential contribution of periapical radiographic film image processing for forensic identification

Potencial contribuição do processamento digital de filme radiográfico periapical para identificação forense

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ABSTRACT

Periapical X-rays are the most common complementary tests in the dental clinic. The indication of image tests in forensic identification depends on the produced X-rays quality. The image processing of conventional radiographs can improve image quality. This study aimed to report the potential contribution of image processing from radiographic films by digitally edited periapical radiographs for case reporting of positive identification. The results of anthropological examinations and dental arches of the victim matched the information transferred by the family of the missing person. The antemortem and postmortem periapical radiographs were digitized on photo scanner (Hewlett-Packard Development Company, HP ScanJet G4050 Photo, United States) and images were processed in Corel PaintShop Pro X4 editing software (Corel Corporation, v14, Canada). The comparison of antemortem and postmortem periapical radiographs digital images allowed to determine 8 concordant points in the contour and delimit the maxillary sinus as well as periodontal and dental structures of the tooth 17. Identification of the individual was possible by digital editing of radiographs in computer software. Editing allowed adjusting image brightness, contrast and sharpness, color temperature and saturation of tooth-jaw structures. Such technological feature effectively contributed to positive identification performed by Forensic Dentistry.

Indexing terms: Forensic identification. Image processing. Radiographs.

RESUMO

As radiografias periapicais são os exames complementares mais frequentes na clínica odontológica. A indicação de exames de imagens na identificação forense depende da qualidade das radiografias produzidas. A edição digital de radiografias convencionais pode melhorar a qualidade de imagem. O presente trabalho consiste em relatar a potencial contribuição do processamento digital de filmes radiográficos através de relato de caso de identificação positiva por radiografias periapicais editadas digitalmente. Os resultados dos exames antropológicos e dos arcos dentários da vítima correspondiam às informações cedidas pelos familiares sobre a pessoa desaparecida. As radiografias periapicais antemortem e postmortem foram digitalizadas em scanner fotográfico (HP Development Company, HP ScanJet G4050 Photo, Estados Unidos) e as imagens processadas no programa de edição Corel PaintShop Pro X4 (Corel® Corporation, v14, Canadá). A comparação das imagens digitais das radiografias periapicais antemortem e postmortem permitiu determinar 8 pontos concordantes no contorno e delimitação do seio maxilar e das estruturas dentária e periodontal do elemento 17. A identificação do indivíduo foi possível mediante a edição digital das radiografias em programa de computador. A edição da permitiu ajustar imagens de brilho, contraste e nitidez e cores de temperatura e saturação das imagens das estruturas dento-maxilares. Esse recurso tecnológico contribuiu de forma efetiva para a identificação positiva realizada pela Odontologia Legal.

Termos de indexação: Identificação forense. Imagem digital. Radiografias.

INTRODUCTION

International organizations recommend the use of photographs, x-rays and tomography for comparing antemortem and postmortem images in identification processes through dental arches¹⁻².

X-rays are the most common complementary tests in dental clinic and are also the most requested to determine the identification of corpses in various putrefaction stages. Frontal and lateral cephalometric, panoramic, bite-wing, occlusal and periapical x-rays are some of the documents that integrate the standard dental record³⁻⁶.

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Dental radiographs allow an accurate documentation record of anatomic-clinical features of dental arches⁷⁻⁸. In Forensic Dentistry Services, the periapical radiography is the most widely used test since it is intraoral, simple, affordable and x-rays the full anatomy of the teeth, periodontium and adjacent bone⁹.

Technical, processing and storage errors of conventional x-rays may result in various losses of antemortem data or contraindicate its use in identification processes. The indication of x-ray tests in identification processes depends, in the first analysis, on the quality of the produced x-ray image.

Digital processing of radiographs allows adjustments of image quality from conventional films by mitigating the technical, processing and storage errors effect, also allowing greater definition of details¹⁰. Tools and controls to adjust temperature, saturation, brightness, contrast, sharpness, highlights, shadows and matrix can be an important resource for indicating x-rays in forensic identification.

The aim of this study was to report the potential contribution of radiographic film image processing in case reporting of positive identification by digitally edited periapical radiographs.

CASE REPORT

A semi-skeletonized incomplete corpse with remnants in colliquative phase was found in a waste disposing field in the metropolitan region of Natal, State of Rio Grande do Norte and was referred to the Forensic Anthropology and Dentistry Service of the Technical and Scientific Police Institute of Rio Grande do Norte.

The victim's skull showed comminuted fractures with bone substance loss in the left and right maxillary region. The dental examination of dental arches revealed the presence of prosthetic, endodontic and restorative treatments and the absence of 20 teeth.

The possible victim's family reported the characteristics of the missing person, Swiss nationality and the presence of gold crowns on posterior teeth. A generic dental treatment cost statement and three dated periapical x-rays were provided.

The anthropological and dental examinations results from the corpse were compared to the family's descriptions regarding the physical characteristics and prosthetic treatments with gold crowns. The comparison results revealed compatible biological profile and

probable dental profile, that is: biological profile: a) male (anthroscopy); b) between 65 and 70 years (methods of cranial sutures and distal ends of fourth rib); c) height between 1,75m and 1,81m (methods of Pearson, 1899; Dupertuis & Hadden, 1951; and Trotter & Glesser, 1952, 1977), and; d) probable Caucasian ancestry (method of Krogman, 1978); dental profile: a) tooth 37 with prosthetic crown preparation with remnants of cementing material; b) tooth 35 with gold crown (metallic incrustation); c) tooth with fractured dental crown and exposure of filling material and; d) tooth 47 with prosthetic crown preparation with remnants of cementing material.

Despite the compatible biological profile and the probable dental profile, it was not possible to confirm the antemortem dental information due to the lack of patient records. However, all the results allowed establishing an identification indicator, from which the primary identification method was applied through the comparison of the antemortem x-rays provided by the family and the postmortem carried out by the forensics.

Due to bone substance losses in the left jaw, only two x-rays of the right upper molar region were used. The time interval between x-rays was a year and a half before the reported disappearance. In postmortem radiographs, periapical imaging was made using the parallax approach and close angulation technique of the antemortem images.

Antemortem periapical radiographs were short of standard quality, presenting technical, processing and storage errors (Figure 1). The low sharpness of radiodensity contrasts and the difficulties to visualize anatomical-clinical characteristics in the light box would contraindicate the use of such images in the identification process.

In order to test the possibility of improving image quality, radiographic films were subjected to image processing. Antemortem and postmortem films were digitized on photo scanner (HP Development Company, HP ScanJet G4050 Photo, USA) with JPEG format file extension ranging dimension parameters of 2032 x 1479, 8-bits depth, width from 2022 to 1971 pixels, height from 1538 to 1479 pixels and horizontal and vertical resolution of 300 dpi.

Digitized files were exported to the image editing software Corel PaintShop Pro X4 (Corel® Corporation, v14, Canada) and edited in the setting palette. The image brightness, contrast, sharpness corrections, color saturation and temperature corrections were manually adjusted until allowing the observation of anatomic-clinical features. The highlights, shadows and matrix settings control were not

changed. Edited images were obtained with parameters ranging the dimension of 2022 x 1471, 24-bits depth, width from 2022 to 1941 pixels, height from 1538 to 1471 pixels and horizontal and vertical resolution from 96 to 762 dpi.

Digitized antemortem periapical x-rays were compared to the postmortem images projected on the computer screen to identify concordant points. Different image and color adjustments produced two different radiographic patterns. Only after the images digital processing it was possible to thoroughly examine the ante and postmortem anatomic-clinical features and determine 8 concordant points in the contour and delimitation of the maxillary sinus, dental and periodontal structures of element 17, which were the (Figure 2):

- anatomy of pulp chamber and horns;
- anatomical contour of the crown and dental roots;
- distal surface enamel contour of the dental crown;
- anatomy of the root canals;
- furcation area;
- lamina dura contour and periodontal space;
- apical region:
- delimitation of maxillary sinus floor.

In this case, digital edition of the radiographic images contributed to the observation and analysis of anatomic-clinical features and, consequently, the determination of concordant points. Therefore, it allowed to scientifically substantiate the technical report as a positive identification conducted by Forensic Dentistry.

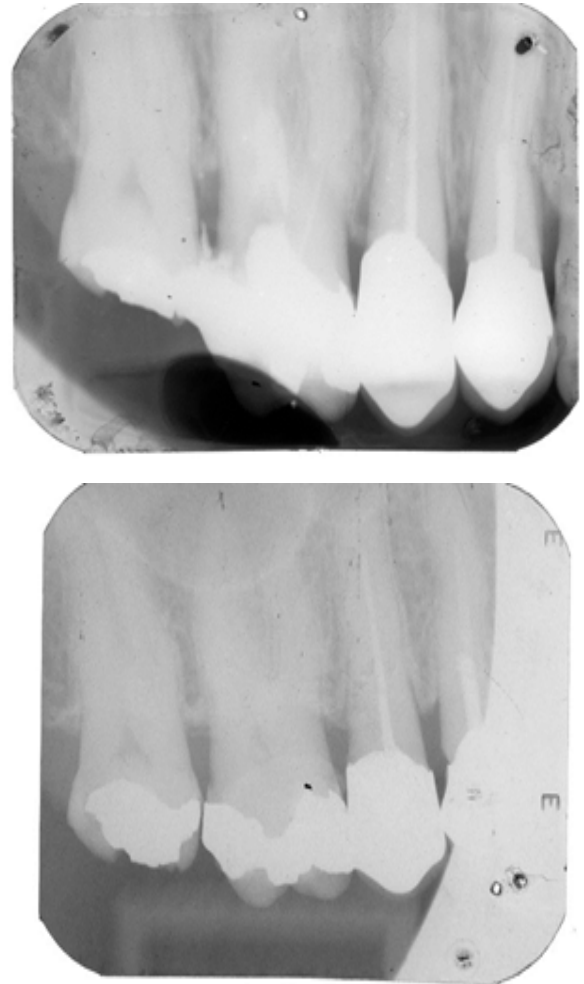


Figure 1. A and B - Antemortem periapical x-rays of dental elements 14, 15, 16 and 17 without digital processing.

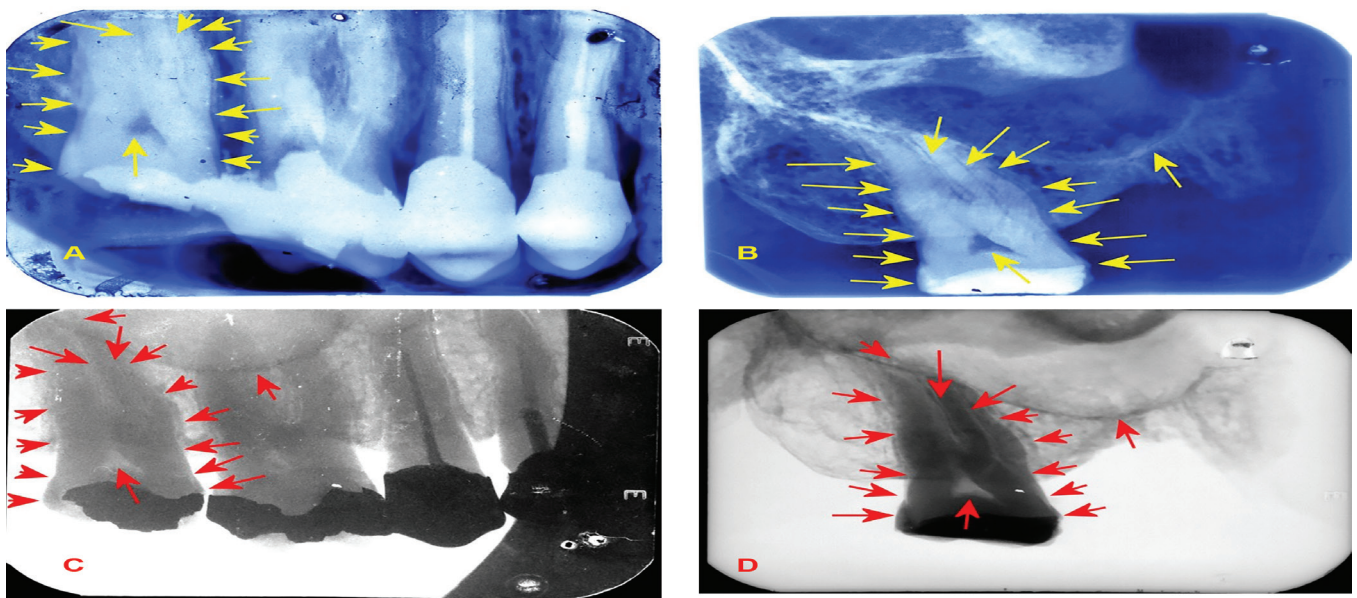


Figure 2. A and C – Antemortem periapical x-rays of dental elements 14, 15, 16 and 17. B and D – Postmortem periapical x-ray of tooth 17. Concordant points in antemortem and postmortem x-rays digitally processed with different image and color settings in the software Corel PaintShop X4.

DISCUSSION

The indication of dental x-rays to determine an individual's identity is a reality in Forensic Medicine and Dentistry services, especially in cases of burned corpses, skeletons in advanced decomposition stage¹¹.

In this case report, the identification method by periapical x-rays was indicated due to the semi-skeletonized state of the corpse and the access to antemortem x-rays.

Despite the anthropological examination for estimating the biological profile, methods developed from the osteological collections of European origin populations were used. The accuracy of anthropological methods was observed in results fully compatible and well defined for the gender, age, stature and ancestry with the physical characteristics described by the missing person family of Swiss origin. In this case, forensic anthropology was important for guiding the corpse through non-exclusion from the identification process.

Despite the information of unusual dental treatment with gold crowns on the missing person, matching with the treatments made or probably found on the corpse, these results were not considered sufficient in this forensic examination to scientifically substantiate the identification report. This conclusion resulted from the impossibility of fully eliminating the chance effect, possible memory biases of family members and, mainly, the absence of dental records able to confirm the information provided by family members about the prosthetic treatments in gold.

In this case, the dental treatment cost statement was the only document available on paper, but it was not used as an antemortem data because it was a generic record of costs, with no initial nor final dental charting records. Furthermore, the impossibility of comparing the execution and type of treatment budgeted in the lost teeth and the lack thereof in the remaining teeth hindered the use of such information.

The absence of antemortem x-rays or poor quality images may contraindicate dental arches examination in such individuals, especially in the presence of clinical records with inaccurate information about treatments and location, dental anomalies, as well as incomplete, erroneous, unavailable or nonexistent initial and final dental charts¹².

The type, location and material of dental restorations is significantly important for individual

identification, however several other oral features can be examined, especially in individuals with few restorations¹². In the reported case, the mesio-occlusal restoration in the tooth 17 could not be used as an identification parameter because it was replaced in the time interval between antemortem and postmortem radiographs.

In the absence of restorations, it is important to consider the dental anatomy, bone trabeculae, pathologies and periodontal tissue features, especially in the face of DMFT reduction and improvement of oral health indexes observed in developed countries and in the Brazilian population¹³⁻¹⁴. It is expected that with increased access to oral health services and adequate ethical practice, an increase in the quality of patients' records should occur with a greater number of data and dental documents.

In this case, the "concordant" terminology was applied to replace the term "coincident" present in the literature. Concordant points are anatomic-clinical features associated with bone and dental tissues individually examined in antemortem and postmortem documents and once compared they show credible concordances between each other.

The preference for "concordant" comes from the information collected about the missing person, which are required to start the identification process of the corpse with postmortem data compatible with the information provided by family members, witnesses or authorities involved in the case. The compatibility of these results serves as an identity indicator. The identity indicator is the strongest occurrence hypothesis to be tested by the scientific method of identification, and it is expected that the compared anatomic-clinical features are partially or fully concordant. This terminology accurately defines the situation, once the definition of the term "coincident" seems to suggest that even with compatible results, forensics was driven by chance or randomly.

It is assumed that concordant points can also represent individualization factors. Individualization factors are specific and consistent concordant points of an individual. In Forensic Dentistry, the observation of one or more individualization factors scientifically substantiates the identification of a person, in a manner that makes them different from others and only identical to themselves.

The comparative analysis between antemortem and postmortem regarding digitally processed periapical radiographs indicated the presence of 8 concordant points. Among these points, 5 individualization factors

were observed: anatomy of root canals, pulp chamber, pulp horns, dental roots and maxillary sinus anatomy. These individualization factors were also observed in other studies^{5,12}. The time interval of one year and a half between the examined radiographs has not changed the dental and bone features observed.

No discordant points were observed, except those justified by losses of jawbone substance and of 20 teeth as well as the replacement of the mesio-occlusal restoration of tooth 17. The relative short time interval between radiographic examinations seems to have no structural implication in the crown contour, distal aspect of the enamel, lamina dura, periodontal space, apical region and furcation area.

In the identification by dental arches, it is difficult to determine the amount of concordant points needed to establish an identity. The dental identification premise is based on the presence of specific and particular characteristics of an individual on the definition of a minimum amount of concordant points^{7,15-16}.

In order to substantiate the technical report of positive identification, the forensic dentist performs a scientific judgement in which not only is the presence of concordant points taken into account, but also considers, in particular, individualizing factors. Quali-quantitative variables should also be weighted, such as frequency in the population, dental documentation in terms of quality and the reliability of the information therein and antemortem data. In this sense, the qualitative approach is sovereign in the context of concordant points count.

Production of radiographs for dental diagnosis, planning and treatment is common practice in dentistry. The forensic applications thereof carry some limitations, since in many cases it is a subjective test, dependent on forensic expertise and the obtainment of radiographic images with the same x-ray incidences¹².

Limitations in forensic investigations may lead to measurement errors between data and experts. Errors generate lack of forensic reproducibility with important legal consequences, since there might be no equal treatment before the law if the dental forensic process is based on non-reproducible forensic examinations.

In order to minimize some of the possible measurement errors, imaging enhancement has been proposed with the creation of standardized databases and the comparison of digitized radiographs¹⁷. Some studies have applied automated methods to increase the identification efficiency and accuracy. Methods work with algorithms that recognize contour patterns and dental structure shapes¹⁸⁻¹⁹.

In forensic practice, overcoming the limitations and contraindications of imaging examinations for identification involves transforming conventional radiographs into digital images, especially when radiographic files are out of quality standards. The indication of x-rays for data comparison is directly related to the quality of images and the type of material presented²⁰.

In dental practice, the main errors that hinder radiographic quality are of technical, processing and film storage nature. The commonest are related to the x-ray incidence direction, coning off, lengthening and shortening, overlap, differences in dosimetry, sharpness and contrasts, yellowish or spotty radiographs, scratched, fingerprinted or partially developed films²¹.

There are several smartphone applications and computer software for image editing that allow controlling brightness, contrast, sharpness, temperature and saturation to improve the quality of dental-maxillo-mandibular images, which, from the forensics viewpoint, may not result in structures or proportion changes.

Digital images still have the convenience of being easily stored, retrieved and transmitted to the examination site, with results in QR code for the antemortem and postmortem data comparison²².

In this case report, the identification difficulty by the Forensic Dentistry was high due to the lack of patient records and poor quality radiographs. However, individual identification was possible using digital editing of periapical radiographs. Image quality improvement allowed the establishment of 8 concordant points, such as the anatomy of the root canals, pulp chamber, pulp horns, dental roots, and maxillary sinus anatomy as robust factors of individualization.

In the case reported herein, the compatibility of results from the anthropological and dental profiles permitted the establishment of an identity indicator and the use of digitally processed periapical radiographs was the parameter required for positive identification of the victim.

CONCLUSION

Conventional imaging tests of poor quality may be digitally processed to increase their potential use in human identification cases. Adjustments to the digital image such as brightness, contrast and sharpness, color saturation and temperature can improve the visualization of dental, bone and dental treatments features. In the case reported herein, digital processing of periapical

radiographs contributed effectively to positively identifying the victim from the determination of 8 concordant points and 5 individualization factors associated to tooth 17 and the maxillary sinus.

Collaborators

GBG EMILIANO was responsible for the case follow-up in the Forensic Institute, working with the forensic dentist

expert and the third author was responsible for the digital imaging processing and, subsequent identification. FS MARINHO was the forensic dentist expert of the case and participated in the paper writing. RN OLIVEIRA was responsible for the case follow-up, working with the forensic dentist expert and the main author in the digital imaging processing for the color adjustments and evidencing of dental-maxillary structures, and participated in the paper writing.

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