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Contributions to the study of common artifacts and errors in conventional and three-dimensional radio-imaging used in the evaluation of odontal, endodontic and periodontal pathology.

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Abstract

Introduction: X-ray radio imaging is commonly used because most diseases in the oral area can only be diagnosed by using this method. Proper identification of elements on a radiological image may also be difficult due to errors that may occur before, during or after the X-ray. These errors are called artifacts.

Aim of the study: The aim of our study is to distinguish the artifacts that can occur on two-dimensional and three-dimensional dental X-rays (intraoral or extraoral) from the actual pathology of the investigated area, by performing control X-rays.

Material and Methods: In our study we viewed, assessed and compared a number of 80 retroalveolar X-rays, 45 orthopantomographs (OPG) and 35 Cone Beam Computer Tomography (CBCT). In case of artifacts or errors, X-rays were repeated within 5 days or a CBCT was performed. In the case of OPGs, another option was to perform retroalveolar X-rays to establish the final diagnosis.

Results: From a total of 80 retroalveolar X-rays, in 13 cases (16.25%) we found artifacts. Of these, in only 4 cases (5%) diagnosis and treatment plan were changed following a clinical examination or a CBCT. In the case of OPGs, out of a total of 45 OPGs, 17 (37.7%) presented artifacts, but only in a percentage of 17.7% (8 cases) they affected the diagnosis. Of the 35 CBCTs, in 10 of them (28.57%) prosthetic works with a metal component or implants were present, with specific artifacts found, but their presence did not influence the diagnosis.

Conclusion: It is necessary for doctors to know the anatomy of the oral region, the most fervent appearance of the components and the different types of artifacts that may occur. Control X-ray is a very commonly used possibility, but there are cases where radiation exposure needs to be minimized.

Keywords: retroalveolar X-ray, orthopantomography, CBCT, artifact, oral diagnosis.

Introduction

Medical imaging is a scientific division that sums up a variety of other sciences to study how to compose, record, communicate, analyze, process and store images of organs and tissues for the diagnosis of various pathologies. One of the branches of medical imaging is dental radio-imaging. Radio-imaging in the field of dentistry can be achieved by means of nuclear magnetic resonance or by means of X-rays.

Nuclear magnetic resonance radiology has a limited use in dental medicine, being used predominantly in the diagnosis of the pathology of the temporomandibular joint (TMJ) [1].

X-ray radio imaging is commonly used because, in the oral sphere, most conditions can only be diagnosed with this method (interdental caries, apical periodontitis, cysts, root fractures, bone support damage, dental implant status).

The radiological image is a complex of two-dimensional graphic representations optically materialized on the radiographic film, the radioscopic screen or the video monitor, corresponding to the anatomical or pathological structures of the investigated region [2].

Currently, in the field of dental medicine, the following types of X-rays are used predominantly:

1. Retroalveolar radiography is intended to investigate teeth and periapical regions, in particular.
2. Endodontic X-ray
3. Bitewing X-ray
4. X-ray with occlusal film
5. Panoramic Radiography (OPG) provides overview of both dental arches and surrounding skeletal structures. Panoramic

dental X-rays are used to diagnose caries, periodontal disease, trauma, pathology of the jaws, supernumerary teeth and for orthodontic evaluation [3].

6. Cranial teleradiography
7. Cone Beam Computer Tomography (CBCT) by three-dimensional imaging (3D) improved the visualization of anatomical structures [4].

Performing an X-ray may result in the detection of unexpected situations. The correct identification of the elements on a radiological image can be difficult for the dentist because of several reasons:

- the human viscerocranium has a complex composition, and on the image the anatomical structures will overlap (orthopantomogram is a 2D representation of a 3D structure)
- incorrect positioning of the patient
- artifacts.

In radiology, the word artifact means an artificial phenomenon occurring on an image reflecting a problem of radiological technique, rather than the actual image of the patient. Recognition of anatomical structures on two-dimensional X-rays is obstructed by the complex anatomy of the middle section of the face, the overlap of different anatomical structures and the change in the orientation of the radiation projection. Objects are viewed in the mesio-distal and apical-coronal plane; however, the buco-lingual plan is not possible to evaluate [5].

Panoramic X-rays are widely used in dental practice, along with bitewing and periapical film X-rays. The clarity of detail is much lower in the case of orthopantomography. Thus the usefulness of diagnosis is limited to the recognition of heavy abnormalities [6]. The panoramic image is a complex projection with multiple overlays and distortions, which can be aggravated by technical errors [7].

With the development of technology, diagnostic methods in dental medicine have been optimized. Cone beam computed tomography is widely used in dentistry because it overcomes the deficiencies of two-dimensional images, projecting the structures investigated into all 3 dimensions (sagital, coronal and axial), removing overlap and deformation [8]. The image quality and diagnostic accuracy of the CBCT are affected by artifacts caused by high-density structures such as enamel and radioopaque materials [9]. The CBCT correctly described all types of defects studied, but involves a relatively high dose of radiation and costs [10].

However, orthopantomography remains the basic imaging method widely available and frequently used to assess dental condition prior to treatment [11].

Very important is the training of doctors to interpret x-ray images [12]. Virtual learning has been proven to be superior to the traditional method [13]. Of course, clinical experience is also very important, in addition to theoretical training. In the case of dentists with theoretical training and extensive experience or experience without formal training, the success rate in interpreting X-rays is higher, approaching 100% [14]. Moreover, training is also needed in the evaluation of CBCT images because computer tapered beam tomography is widely used by dentists [15, 16].

The aim of our study is to distinguish the artifacts that can occur on two-dimensional and three-dimensional dental X-rays (intraoral or extraoral) from the actual pathology of the investigated area, by performing control X-rays.

Material and methods

For this study we viewed and compared a number of 80 retroalveolar X-rays, 45 OPGs and 35 CBCTs. We used 2 radio-imaging systems: X-Ray Soredex for retroalveolar radiography and OPG, and for CBCT we used i-CAT Scanner with OnDemand rendering and visualization software. In the case of X-rays showing artifacts or possible errors, X-rays were repeated at a maximum interval of 5 days or a CBCT was performed, and in the case of OPGs, retroalveolar X-rays were performed to confirm or disprove the diagnosis.

Prior to the interpretation of the radiographic images, the optimal conditions were ensured, which helped to remove artifacts arising from the use of an inadequate technique of making and processing the radiological film, by using obsolete apparatus, damaged films, misadjustment of the apparatus, positioning and improper diaphragm of the apparatus.

Also, due to the fact that today radiology has evolved and is being done digitally, the artifacts related to the processing of radiological film in the darkroom have been removed.

The interpretation of the X-rays was based on their visualization, both using the negatoscope and in digital format. It ensured the possibility of adjusting the brightness and size of the images, which are real benefits for the correct interpretation of the radiographic images. Thus, it was possible to eliminate some technical errors in the examination of X-rays.

Important to note is that in our study the interpretation was carried out by both methods. Control X-rays were performed only when the artifact/error affected the diagnosis. Many of the artifacts listed and found on the films or X-ray images do not pose diagnostic problems, and in those cases, we considered a second exposure of the patient to radiation useless.

Also, if the differential diagnosis could be made by clinical examination, the second X-ray was avoided.

Results

In the group of 160 radiological investigations, we encountered the following types of artifacts:

1. "Burn Out" effect (mesial and distal cervical radio transparency) (figure 1);
2. Radiotransparent artifacts (which can mimic fractures, cysts, apical periodontitis, tumors, secondary cavities or relapses of caries) (figure 2);
3. Radiopaque artifacts (which can mimic tumors, root debris, included teeth) (figure 3);
4. Blurred image (figure 4);
5. Elongated image (figure 5);
6. Mechanical effect (figure 6);
7. Jewelry projected on film (radiopacities) (figure 7);
8. Overlapping of anatomical planes;
9. Bright effect (figure 8).

Figure 1. Burn-out effect

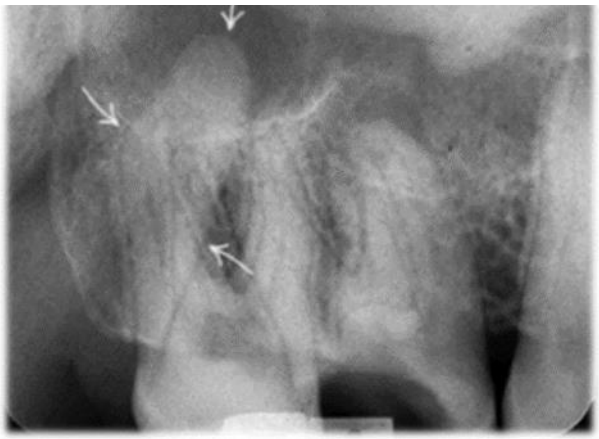

Figure 2. Radiotransparent artifacts – anatomically induced by coronoid process overlapping on the molar roots

Figure 3. Radiopaque artifacts

Figure 4. Blurred image

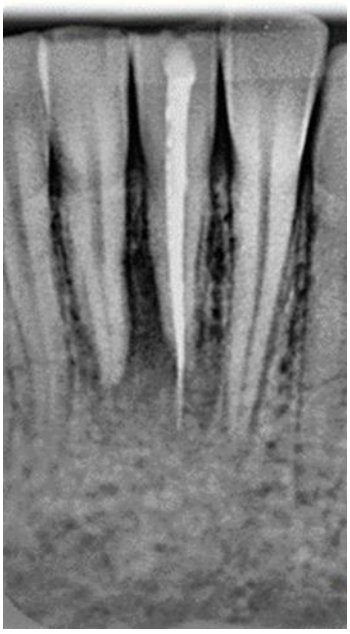

Figure 5. Elongated image

Figure 6. Mechanical effect

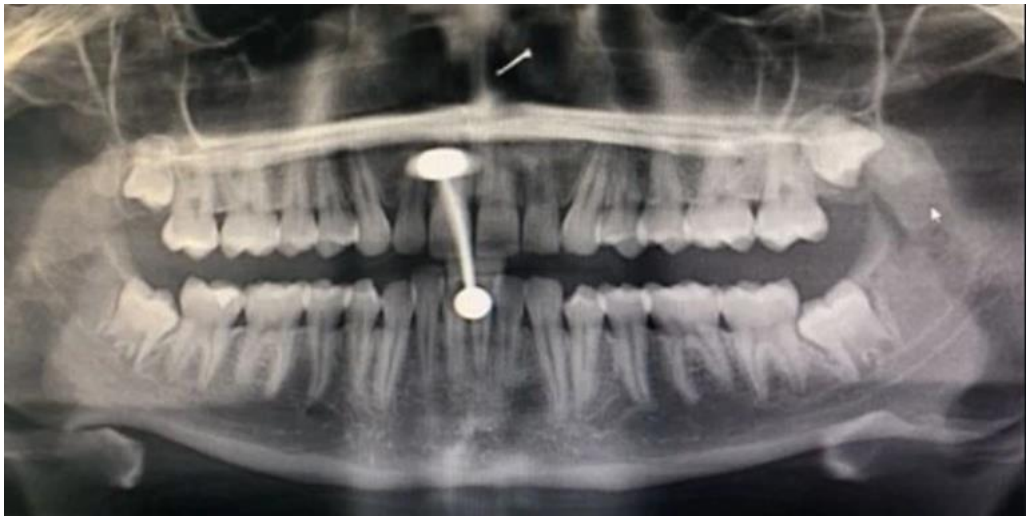

Figure 7. Jewelry projected on film

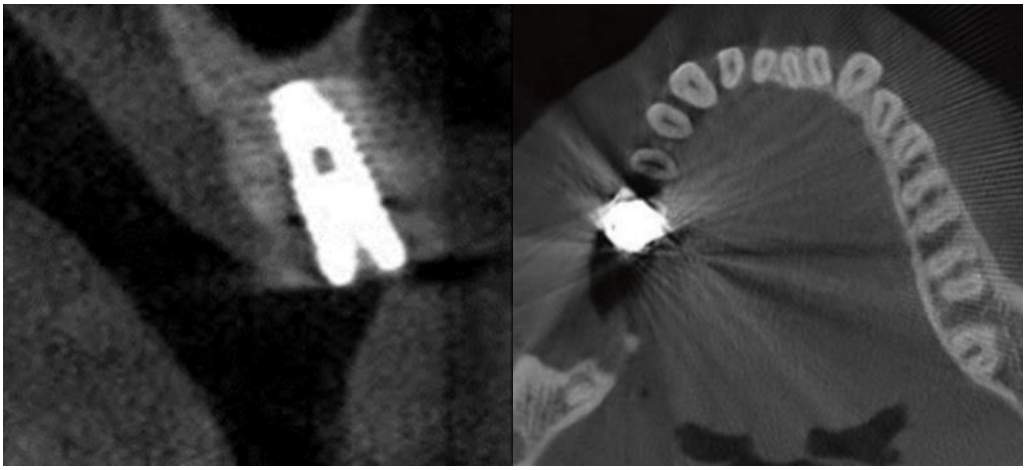

Figure 8. Bright effect

Of the total of 80 retroalveolar X-rays, in 13 cases (16.25%) we found artifacts. Of these, in only 4 cases (5%) diagnosis and treatment plan were changed following a clinical examination or a CBCT. In the case of OPGs, out of a total of 45 OPGs, 17 (37.7%) presented artifacts, but only in a percentage of 17.7% (8 cases) they affected the diagnosis.

Of the 35 CBCTs, in 10 of them (28.57%) prosthetic works with a metal component or implants were present, with specific artifacts found, but their presence did not influence the diagnosis (figure 9).

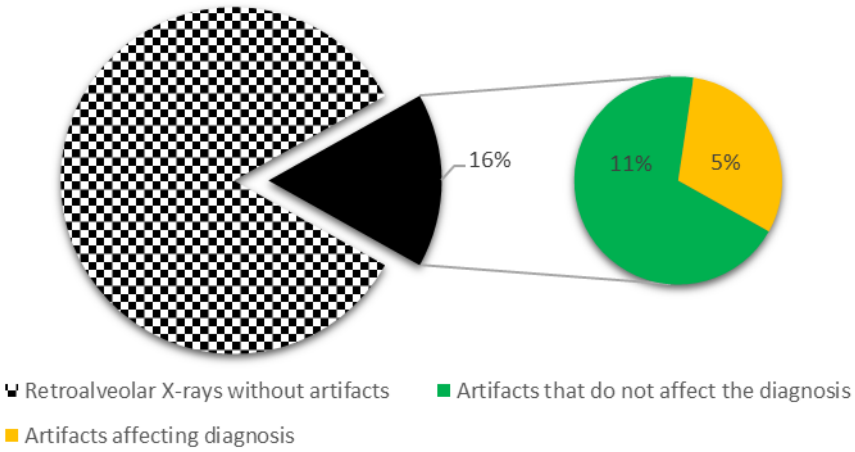

Figure 9. Graphic representation of the situation found in retroalveolar X-rays

Of the 80 retroalveolar X-rays, artifacts were found in 13 of them. The artifacts found in these 13 X-rays were as follows: burn-out effect, elongated image, blurred image, mechanical effect and overlapping anatomical planes. One of the X-rays had a burn-out effect, and a second X-ray was not performed in this case. However, 12 of them required further imaging investigations. In 4 cases the additional investigations resulted in the establishment of a new diagnosis and implicitly a new treatment plan or lack thereof (in case of the occurrence of the burn-out effect). Of these, in three cases it was necessary to carry out some control CBCT's.

The visualization of the 45 panoramic X-rays images led to the discovery of artifacts in 17 of them, in a percentage of 37.7%. Further investigations were carried out in 12 of the 17 cases, and the final diagnosis was modified in 8

cases. In three of the panoramic X-rays there was no need for a control X-ray because the artifact present was a radiopacity, due to the presence of jewelry in the investigated area. Also, in two other panoramic X-rays, the burn-out effect was found, the differential diagnosis being carried out by clinical examination.

In the case of CBCTs, the situation was different from the rest of the investigations. So, although out of the total of 35 CBCTs viewed, we found artifacts in 10 of them, the artifacts were caused by the presence of metal-component prosthetic works or implants, presenting themselves as light artifacts specific to this type of investigation. Unlike other types of radiographic representations, in their case the artifacts did not require a change of diagnosis.

Summarizing the results of this study, it can be specified the 15% percentage in which another X-ray was needed. Although one-fourth of X-rays (40 out of 160) presented artifacts, only 24 of them overlapped with key elements in the diagnosis, thus requiring the resumption of investigations (figure 10).

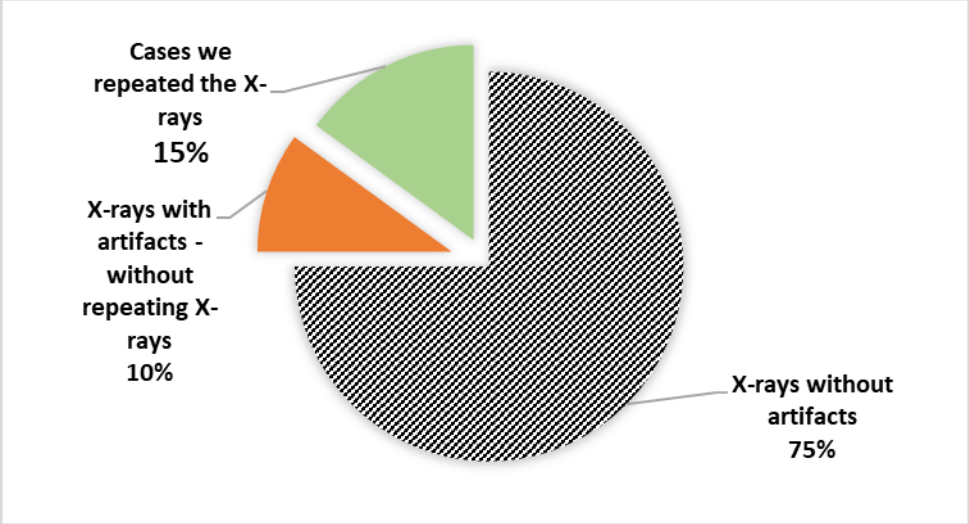

Figure 10. Percentage of X-ray repeated due to the appearance of artifacts

Of the 40 radiological investigations with artifacts, 13 were found in the interpretation of retroalveolar X-rays, 17 artifacts in the interpretation of orthopantomography and 10 in the interpretation of CBCT sections. Although a difference is already observed between these 3 types of radiological investigations and it can be specified that panoramic radiography is the most susceptible of these to the appearance of artifacts, percentages will create a much clearer picture.

In the case of retroalveolar X-rays, artifacts occurred in 16% of cases, in the case of panoramic X-rays, in 37.7%, and in the case of CBCT sections in 28.57%. It can therefore be observed that the largest percentage was in the panoramic X-rays.

On the other hand, diagnostic errors can also occur when interpreting panoramic X-rays. It is noted that the diagnosis was changed (after further investigation) to 8 out of 45 OPG and to 4 out of 80 retroalveolar x-rays. So, although fewer OPGs were investigated, they suffered several errors in interpretation.

Discussions

Radiological investigations in dental medicine are indispensable in establishing a correct diagnosis and an appropriate treatment plan. Different radiological investigations show different types of errors likely to occur, with different sources. Very susceptible to the appearance of artifacts are, however, panoramic X-rays [16]. Thus, out of the total of 45 OPGs investigated, although 17 of them presented different types of artifacts, 8 underwent diagnostic changes, 2 of which only needed a thorough clinical examination, which excluded possible parcel caries, questioned due to the occurrence of the burn-out effect.

In addition to this, panoramic X-rays benefit from a fairly low clarity of detail, so their diagnostic power does not apply to small conditions. Also, the clinical evaluation of mesio-distal angulation of the teeth on this type of X-ray will be approached with caution, while understanding the distortions that may occur [17].

The quality of panoramic X-rays could be improved by improving the radiographic technique [18]. This detail was taken care of when the imaging investigation group was chosen. However, the radiographic technique is a variable that cannot be quantified. So we were only able to approximate and minimize these types of artifacts.

Despite the obvious disadvantages we have exposed, orthopantomographs remain basic imaging modalities [18], dental emergencies being reasons why we frequently use them as diagnostic tools [19].

In general practice, the percentage of repeated X-rays is more than 10% [20]. Our study revealed, from the group of 160 radiological images investigated, a percentage of 25% (40) X-rays with artifacts, of which 15% needed control X-rays to be performed.

Although we encountered artifacts in 25% of X-rays, not all required additional radiological investigations. It can therefore be seen from this detail that a thorough clinical examination, increased attention in viewing the image, adequate illumination and last but not least, theoretical knowledge of medium or higher level, are extremely important.

Of course, diagnostic errors due to the overlap of several anatomical planes occurred in our study as often as in the case of panoramic X-rays. Although this is a normal aspect of X-rays in two dimensions, we have framed it with the other artifacts because it is most susceptible to the appearance of diagnostic errors. This type of artifact occurs in both periapical and panoramic radiography, in a significant proportion. In the case of retroalveolar X-rays, this artifact was found in 8.75% of cases, and in the case of panoramic X-rays in 15.5% of cases.

A way to avoid this inconvenience is 3D X-ray which, however, is not always necessary. CBCT also has some drawbacks, such as artifacts. Such structures can occur due to the patient's movement, the process of capturing and reconstructing images [21].

The percentage of occurrence of artifacts in this study is 28.57%. Compared to data from literature where the values of artifacts ranged from 6.1% to 27.4% for titanium and between 10% and 43.7% for lead, we can say that our study data folds those previously discovered [22].

Image optimization methods improve the quality of the image, but significantly increase the number of artifacts that negatively affect the diagnosis [23].

During the study we experimented with different methods of "improving" images when using the digital method, but not all of them helped. What we noticed was that the function of increasing the size of the X-rays and opening/closing the luminosity function helped the most. The contrast change only helped in some cases, and the one to improve clarity was not helpful.

Understanding the reasons why artifacts appear on radiological images and studying how to prevent them are of high clinical importance [24].

Theoretical training, although it is imperiously required, is not a substitute for practical experience. From the point of view of a sixth year student who carried out this study, I can say that the requirement to correctly and completely evaluate a certain radiographic image is a real challenge. The wealth of information that any image provides can generate errors in diagnosis. Ease of interpretation comes with experience, which I also observed during this study.

Conclusions

1. In order to be able to distinguish between artifacts, errors in radiological paraclinical investigations and osteo-dental anatomy or pathological conditions themselves, it would be necessary for practitioners to know the anatomy of the region, the phisiological appearance of the components, the source of errors and the different types of artifacts that may occur.
2. In the context of the interpretation of a CBCT, there are artifact correction systems and image interpretation techniques that help to eliminate these errors and ensure a

clear and accurate picture of the structures. Similarly, there are different methods of removing artifacts in the case of other types of X-rays, which can be used to reduce the need for further investigation.

3. By increasing the number of continuing education programs, the CBCT applicability can be sustained and may improve general dental practice for all specialties. Including the study of the CBCT imaging as a potential imagistic investigation in dental education is essential and the advantage can be found in the accuracy and reliability of treatment planning using 3D imaging and in the results evaluation.

Conflict of interest: None declared.

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