Characterization and Analysis of the Physical Parameters in Dental X-Rays Phantom

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Abstract— All care related to ionizing radiation exposure to patients, the radiographic image quality and gain time is related to quality control equipment and image. Therefore, it is necessary to be realized by using quality control and intercomparison phantom images with the results of previous tests as well as other types of X-ray equipment, or performing the intercomparison of results of quality control testing. The objective of this study was to characterization, and analysis (intercomparison) results periapical radiographs obtained with phantom and evaluate the high and low contrast in dental radiographs service of Maraba, northern Brazil. For the intercomparison of physical parameter of high and low contrast in the periapical radiographic equipment of the Maraba, a phantom developed in Brazil was used precisely in Aracaju, northeastern. It is worth noting that, the phantom used in this work and the interparameter of the equipment of the images showed satisfactory results bringing out the difference from the standard image. However, tests can be used to switch to other equipment in the surrounding towns of the city of Maraba. Thus allowing the cornerstone for the creation of a database with images obtained with the phantom and can be used in training of students and dental professionals.

Keywords— **X-rays, Dental Phantom, Quality Control.**

I. Introduction

The equipment of dental X-rays are commonly used for image acquisition and verify some type of anomaly or study related to accurate diagnosis, such as molar, adjacent anatomical structures and channel structure dental. On intra oral procedures all radiographs are obtained with intra oral film that can be positioned in three ways, periapical, occlusal and interproximal [1-3].

In the intra oral procedure, particularly in the periapical way, the radiography is performed to show the structure of the individual teeth and tissues around the apex so deliver the detailed anatomical structure surrounding the tooth and alveolar bone. In this sense, the main features observed in dental radiography is the detection of apical infection or inflammation, the root reviewed before extraction, evaluation after trauma to the teeth and associated alveolar bone, detailed assessment of apical cysts and other lesions within the bone alveolar [4].

Some changes in dental X-rays images occur due to temperature variation, developing solution, conditioning the radiographic film, patient positioning and especially of calibration of the image acquisition equipment. In that sense, it is necessary to the maintenance and prevention of the equipment, respecting the periodicity of quality control tests recommended by the National Health Surveillance Agency (NHSA), ordinance 453/1998 [5].

Tests for detecting anomalies of the teeth and surrounding region can be observed through dental radiographic image [6]. In that sense, the dental radiographs are commonly obtained within 20 to 40 cm, distance source-receiver (DSR). It is worth mentioning that, most dental X-ray equipment is provided with the circular collimation, which determines the shape and the beam size that leaves the x-ray tube and reaches the patient. Therefore, it is recommended that the presence of a professional to position the patient [7-10]. Thus, it is necessary that the X-ray equipment before being handled is inspected and that the quality control tests are in line with national and international standards.

All care related to ionizing radiation exposure to patients, the radiographic image quality and gain time is related to quality control equipment. Any negligence in image processing and maintenance of X-rays can often lead to error in getting the image. Therefore, it is necessary to be realized by using quality control and analysis phantom images with the results of previous tests as well as other types of X-ray equipment, or performing the intercomparison of results of quality control testing.

The objective of this study was to characterization and analysis (intercomparison) of the results periapical radiographs obtained with dental phantom and evaluate the high and low contrast in dental radiographs service of Maraba-Para, northern Brazil.

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II. METHODOLOGY

For the analysis of physical parameter of high and low contrast in the periapical radiographic equipment of the Maraba, no State Para, a phantom developed in Brazil was used precisely in Aracaju, northeastern Brazil, by Belinato [7]. The phantom possesses cylindrical, metal mesh inside dimensions of 40, 60, 60 and 100 lines per inch for the evaluation of regions of high and low contrast. Figure 1 represents the phantom of high and low contrast and all dental X-ray. It is noteworthy that the phantom has a tooth anomaly, stuck with a red wax to check the resolution of the images in each equipment of dental X-rays and so, through the tests one intercomparison between the equipment was performed by the images obtained with the phantom.

Fig. 1 Phantom of high and low contrast and all dental X-ray.

In the intercomparison of results from periapical radiographs obtained with phantom, we evaluated 30 radiographs obtained in 15 dental X-ray in the city of Maraba, State of Para, northern Brazil. For each device, we performed two images acquisition and observed the presence or artefacts little sharpness in the details of the anatomical structures of the tooth, as well as high and low contrast and visualization of metal mesh inside dimensions of 40, 60, 60 and 100 lines.

In this work, additionally, is employed Raman spectroscopy as an aid to assess the influence of radiation in acrylic phantom used in high and low contrast technique. The Raman Effect is a kind of scattering that occurs simultaneously to the Rayleigh scattering phenomenon which refers to the inelastic scattering of light by matter. The differences between the incident and scattered frequencies are equal to the vibrational modes of the material [11]. Raman spectroscopy is based on the detection of the scattered light being a widely used technique in the study of dental materials, including, serving for the characterization of acrylic resins, which provides chemical and structural information of these materials. As it is expected that the phantoms developed can be reused many times, it was considered necessary to evaluate possible changes in composition due to irradiation with radionuclides. Analyses of micro hardness and elastic properties of acrylic samples were performed in Shimadzu equipment (DUH-2115), in the load-unload mode with a force of 100 mN and hold time of 4 s. The hold time is the time that the diamond stands still when it reaches the maximum force applied. To these analyses, five samples of $3 \times 3 \times 1$ cm^3 were prepared (Fig. 2). Samples had a density of 1.15 ± 0.06 g/cm^3. Samples densities were obtained through experiments by Archimedes' principle.

The acrylic resin samples were irradiated using gamma rays from ^{60}Co source of Gammacell 220 equipment. We investigated non-irradiated and irradiated samples with doses of 1, 10, 30 and 50 kGy.

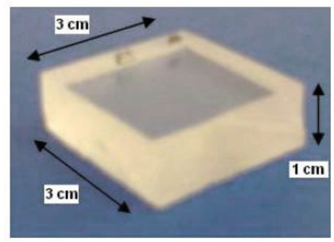


Fig. 2 Acrylic resin sample.

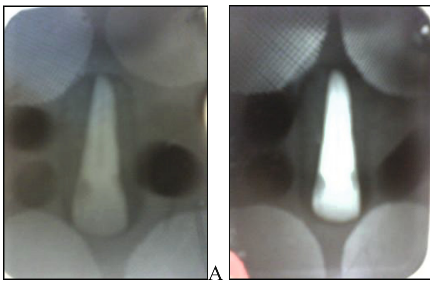
After irradiation of the specimens, the analysis of hardness and elasticity were performed. Analyses were performed on a Shimadzu equipment (DUH-211S) Dynamic ultra-micro hardness tester, the load-unload mode with a force of 100 mN and hold time of 4 s [12]. The hold time is the time that the diamond remains stationary when it reaches the maximum force applied. This micro-durometer belongs to the Laboratory of Physics, Federal University of Sergipe. In the experiments of the Raman dispersive Raman spectrometer model SENTERRA® manufactured by Bruker Optik®, with the helium-neon laser of wavelength 633 nm (red) was used.

For the analyzes, we used laser power of 10 mW, a 20x objective lens (magnification), spectral range of 400 - 1800 cm^{-1} with a resolution 3-5 cm^{-1}, thus covering the main vibrational modes of acrylic.

It is noteworthy that the tests carried out in acrylic specimens were to corroborate the results, whether there was interference in the images due to the amount of radiation in the material, thus ensuring security of the tests, only in high radiation dose rates can damage the acrylic.

III. RESULTS AND DISCUSSION

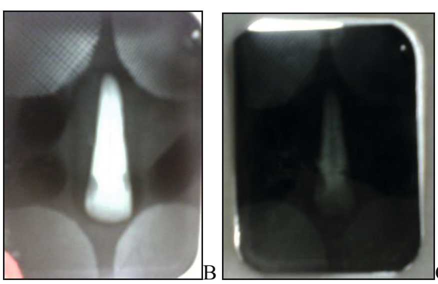
The results of the analysis images were used as parameter for the analysis images obtained with a dental radiology equipment brand Dabi Atlante, in the city of Maraba. From this, it was found that the images obtained in the offices have satisfactory results for inter-equipment. It is worth noting that the image obtained with the phantom showed worrying results regarding radiation protection. The images have low sharpness in the details of anatomical structures in most equipment. In this sense, you realize that dental X-rays require urgent preventive maintenance and calibration. Some images are not structured to show as little the tooth and the visualization of cloth are, thus exhibiting a low resolution in the image (Fig. 3).



A B

Fig. 3 Representation the images obtained with the phantom (A and B).

Another important factor in the analysis of the images was the high and low contrast, comparing the images **A** and **B**, we observed that exposure of radiation on the metal mesh of the phantom was not possible to identify which mesh sizes, so due to lack of standard image quality performing radiographs in a and **B**.



B C

Fig. 4 Representation the images obtained with the phantom (B and C).

Intercomparison the image **B** to **C**, one can clearly see the difference between them, namely: the details of the meshes in the image **C**, a darkening image, thus losing the information that the image should present in it, that is a low resolution quality with no details of the grating mesh size and geometry of the tooth.

The image **C**, the low contrast further damaged the image resolution without definitions of metal mesh are not recommended. In this sense, it is not possible to visualize anatomical structures, the detection of apical infection or inflammation, the root reviewed before neither extraction, detailed evaluation of apical cyst nor other lesions within the alveolar bone.

In Fig. 5, one can observe a good quality image resolution in **D** with respect to image **E** clearly the details of anatomical structures.

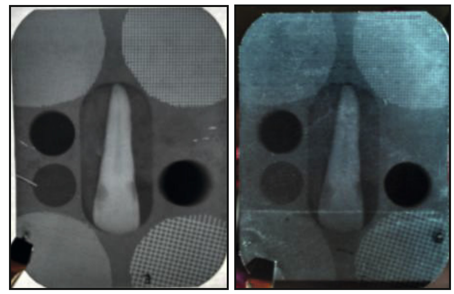


Fig. 5 Presentation the images obtained with the phantom (D and E).

The evaluation parameter of the images for the analysis of the results was defined from the preview images of the tooth anomalies. We observed that 48% of dental radiological equipment showed no abnormalities details of the tooth, with a low resolution image in, presence of artefacts and some images do not show the sharpness of wax that was around the tooth. However, 52% of the equipment presents satisfactory results.

Another important point observed in the samples analyses, comparing non-irradiated and irradiated, is that the gamma radiation exposition caused a gradual darkening of these materials. Visual observation showed that the non-irradiated specimen (leftmost in Fig. 6) presented a more clear that the samples irradiated. Likewise, the specimen irradiated with 1 Gy (central samples in Fig. 2) was colorless that the irradiated with 10 Gy.

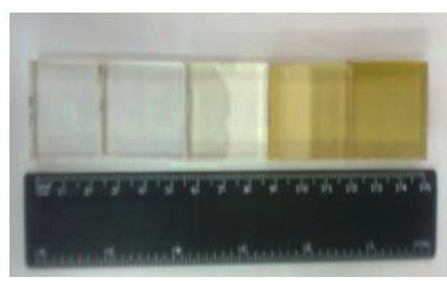


Fig. 6 Picture of pink auto polymerizing acrylic resin sample non-irradiated and irradiated.

For colorless acrylic acquired in plates used in the construction of the object high and low simulator contrasts (for Walmir Belinato) [7] was found for the micro-hardness Vickres values between 14.57 and 15.14 HV; i.e. between 142.9 and 148.5 MPa, and the elasticity between 3.89 and

4.02 N / mm^2. The hardness measurements of acrylic specimens showed relatively good performance compared to the values obtained by Goncalves *et al*., (2001) and Tenji *et al*. (2004) [13-14]. For example, the first authors found the knoop hardness values between 14.5 and 18.1 (142.2 and 175.5 MPa) to the colorless acrylic. The following knoop found the hardness between 14.64 and 17.56 (143.6 and 172.2 MPa) for acrylic auto-polymerizing pink. The Vickers' name or knoop indicate the same hardness values, although obtained by testing with different characteristics.

As hardness and elasticity, the specimens did not change significantly. It can be stated that these materials showed resistant to radiation doses to which they were exposed (up to 50 kGy of gamma radiation from cobalt-60), indicating that the built phantoms not suffer significant damage after repeated use, because the doses issued by dental X-rays are usually low compared to those applied in the specimens analyzed in this work. Additionally, the radiation energy range of 60 Co is 1.25 MeV, as energy range of dental X-ray equipment is in the range between 50 keV and 70 keV.

Uncertainties obtained for the hardness and elasticity values were estimated by the operating system equipment itself. The hardness of the acrylic specimen non-irradiated showed a value of 14.89 HV. The samples irradiated with Co-60 had an average of 1.73% reduction in hardness compared to non-irradiated specimen. The biggest difference found between elasticity results of the test piece of non-irradiated and irradiated acrylic was 3.3% with 1 Gy dose.

Another important factor observed in the analysis with the samples, comparing non-irradiated and irradiated, is that radiation exposure caused a gradual darkening in the material (acrylic). Visual observation of them showed that the non-irradiated specimen (left, presented in Figure 6 is clear that the irradiated specimens). Similarly, the irradiated specimen with 1 Gy (specimen center) showed clear that the irradiated with 10 Gy.

Therefore, it is concluded that the longer the exposure, the damage is perceivable, as well as for the more acrylic phantom usage time to achieve the lowest quality control testing the efficiency of the material. However, they are not perceptible changes in quality control testing of dental X-ray equipment.

It is worth noting that, the phantom used in this work and the inter-parameter of the equipment of the images showed satisfactory results bringing out the difference from the standard image. However, tests can be used to switch to other equipment in the surrounding towns of the city of Maraba. Thus allowing the cornerstone for the creation of a database with images obtained with the phantom and can be used in training of students and dental professionals.

IV. Conclusions

Through analysis of the images, it was shown that through inter periapical radiographs obtained with dental phantom it was possible to evaluate the dental X-ray equipment in Maraba. Just as, in regard to the standard of image quality was possible to observe the difference between the X-rays such as assess high and low contrast, anatomical tooth structures and artefacts. Another relevant aspect is that the intercomparison of images obtained in dental radiology Maraba can contribute significantly in the ratings of other equipment of dental X-rays from the cities of the South and Southeast of Para, northern Brazil. Therefore, the analysis of the physical parameter may also be used for continuing education for radiology professionals.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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