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Design and development of an alignment test device for clinical X-ray equipment with 3D print and low-cost materials

Miranda[a] E.H.A., Assunção[b] M.F.M., Silva[a] J.O.

[a] *Universidade Federal de Goiás/Instituto de Física,Goiânia,Goiás,Brazil*

[b] *Secon Serviços de Radioproteção, Goiânia, Goiás, Brazil*

ed_he@discente.ufg.br

ABSTRACT

In this paper is presented the design and development of a low-cost device for the Alignment Test, one of the quality tests for radiodiagnostic equipment. The device was designed with open-source software and was built with a 3D printer. Our focus was to create a model with low-cost, that can be easily produced and handled. The prototype was tested on a conventional radiodiagnostic equipment and presented satisfactory results considering the initial goals.

Keywords: **Alignment Test, 3D Print, Low-cost materials, Quality Assurance, Radiology.**

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1. INTRODUCTION

According to a 2008 United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) report [1], medical diagnostic radiology is the main source of human exposure to ionizing radiation. For that reason, it is essential to keep X-ray imaging equipment under national and international well-established standards, in order to avoid unnecessary exposure.

For a proper dose evaluation and image quality in conventional radiology, various quality control tests are needed. One of them is the X-ray central axis alignment test, or simply the alignment test. With the alignment test, is possible to verify if the X-ray beam central axis and the image receptor plane are properly aligned. This test is commonly performed with an alignment test device. Figure 1a shows the device idea, the alignment test device consists in two radiopaque spheres alignment alongside the vertical axis, one on the top side and one on the bottom side of the device. To perform the test, it is necessary to image this device along the vertical axis. If the equipment is perfectly aligned, only one sphere will appear in the image (the sphere's projections will be on top of each other); if not, we can measure the theta angle (Figure 1b) based in the distance between the sphere's projections in the image.

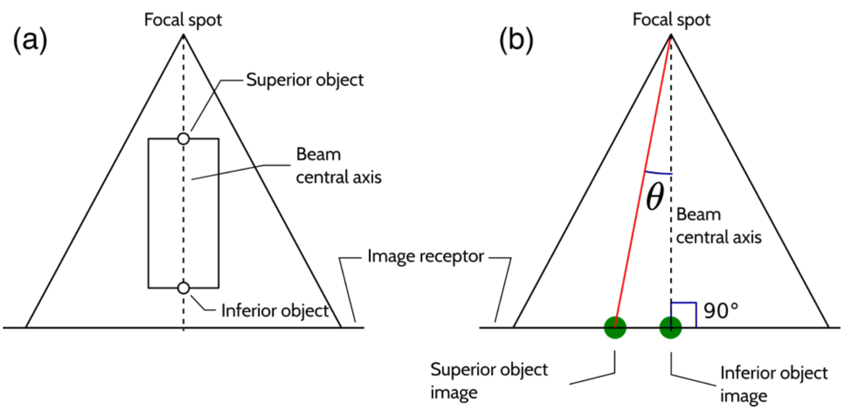

Figure 1: *Sketch of a generic alignment test device. (a) Device position in an X-ray beam, presenting the superior and inferior radiopaque objects. (b) Evaluation of the beam central axis alignment with the device*

According to the Agência Nacional de Vigilância Sanitária (ANVISA) Normative Instruction 90 [2], which regulates the operation of conventional radiology rooms, this quality control test has a tolerance level of 3° in relation to the perpendicular axis to the image receptor plane, as presented in Figure 1b. This test can be applied to conventional equipment and digital ones [3], and is also necessary in fluoroscopy radiology [4]. If the equipment is operated with a misalignment greater than 3°, distortions may appear in the image, leading to a poor image quality, which can increase the patient dose by the necessity of a new patient exposure. This test is so important, that needs to be performed with a six months periodicity [2].

Usually, the alignment test is performed with commercial devices, that are made of acrylic or fiberglass. These commercial devices may be expensive to be acquired for small medical imaging diagnostic clinics in developing countries, such as Brazil, and this can result in a non-compliance of the standard [5].

Because of that, and with the growing use of devices made with 3D printers in hospital environment [6], we propose the design and development of an alignment test device for clinical X-ray equipment using a 3D print and low-cost materials. 3D printers show versatility in their applications, and they can be used to make this important quality test device more accessible to clinics in Brazil.

2. MATERIALS AND METHODS

The alignment test device developed in this work consists in a structure that holds two radiopaque spheres, with 0.8 mm diameter, aligned along a vertical axis. The spheres were taken from two ballpoint pens and are made of a tungsten alloy [7].

The device was sketched using the free app TinkerCad®, and an Anet A8 DIY 3D printer (Figure 3) was used to print it. Its structure is made with black PLA (polylactic acid), a thermoplastic polyester that is very common in building 3D models and prototypes. Both, the printer and the PLA, are from the *Instituto de Física da Universidade Federal de Goiás* (IF/UFG). The device sketch and the printed prototype are presented in Figure 2. The vertical distance between the spheres is 15 cm, which is commonly utilized in the commercial devices. The upper and the bottom surfaces have 4 cm in diameter. Each one of them have conical holes that were drilled to keep the spheres fixed during the experiments, as can be seen in Figure 4.

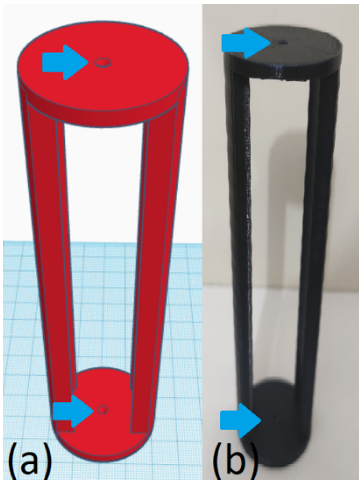

Figure 2: *(a) Device sketch made with the TinkerCad® app (b) The printed prototype. The arrows show the conical holes made to keep the spheres fixes during the experiment, the upper and the bottom surfaces have 4 cm diameter*

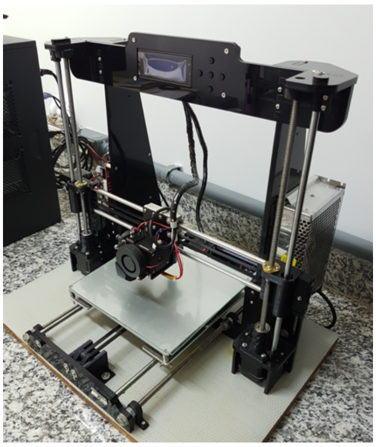

Figure 3: *Anet A8 DIY 3D printer used to print the device*

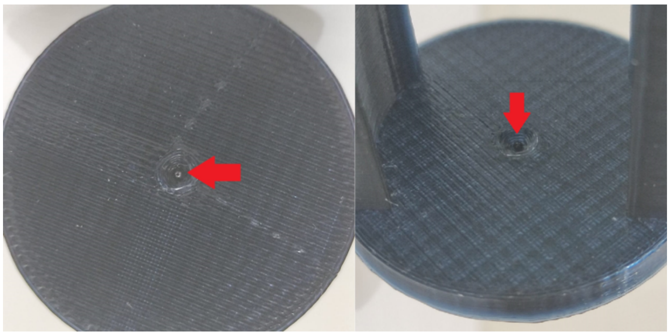

Figure 4: *Both spheres positioned in the device. (a) Upper surface (b) Bottom surface*

Another device was developed to be used as reference to measure the misalignment during the test. This device was called the guide table, and it is rectangle flame of 18x14 cm² with two concentric circles on its center with 1.0 and 1.7 cm diameter. The dimensions of the circles were calculated using the tangent of the theta angle formed by the triangle with both spheres' projections and the upper sphere position; the calculation is based on Figure 1b, and it follows the same dimensions of commercial devices [8].

The guide table design was also developed using TinkerCad® and it is based on a printed circuit board, as presented in Figure 5. The lines presented in the guide table are made of aluminum, with enough thickness to be radiopaque in conventional energy techniques. It has bidimensional axis with scales of 1 cm and it can be used to perform a field size test [2].

The field size test verifies that the luminous field match the radiation field. According to [2], this test has a 4º tolerance, and also needs to be performed with a six month periodicity. To perform this test, is necessary to adjust the luminous field to the guide table sides, after the exposure, the field deviation is verified on the image (Figure 7). A good match between these field sizes reduces the scattered radiation, which guarantees that only the region in interest is irradiated.

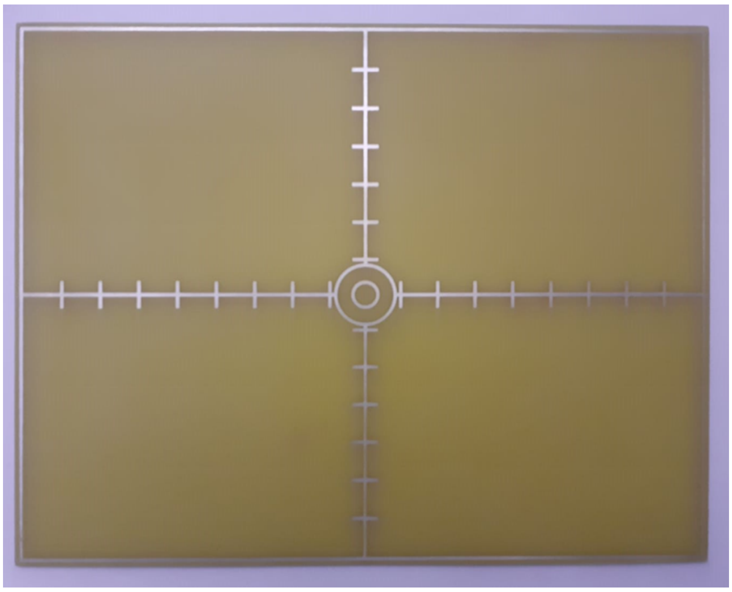

Figure 5: *Developed guide table device*

To perform the alignment test, the alignment test device and the guide table were positioned on a digital radiology equipment GE Healthcare, model DR-F. The exposition parameters were 50 kV tube peak voltage and a 5 mAs tube current-time product, with a field dimension of 18x14 cm^2 (to fit the table). The experimental setup is presented in Figure 6.

Figure 6: *Experimental setup*

To further our analysis, we performed the same test using commercial devices (CQ-09 *Teste de Alinhamento de Feixe*, CQ-12 *Teste de Colimador*) [8], in order to compare the results.

3. RESULTS AND DISCUSSION

The first test performed was to image the guide table alone, in order to see if it would clearly project the table information in the image (Figure 7). As expected, the aluminum lines have enough thickness to project all the table information. Note that this image is useful to perform the field size test, we adjusted the beam field size to the guide table size (18x14 cm²), the fact that the image doesn't perfect fit the table sides show that the equipment has some deviation, is possible to measure this deviation using the table image combined with an image software (a better measure than the visual test), doing this we verified that the equipment is according to [2] tolerance. The same result was obtained using a commercial device.

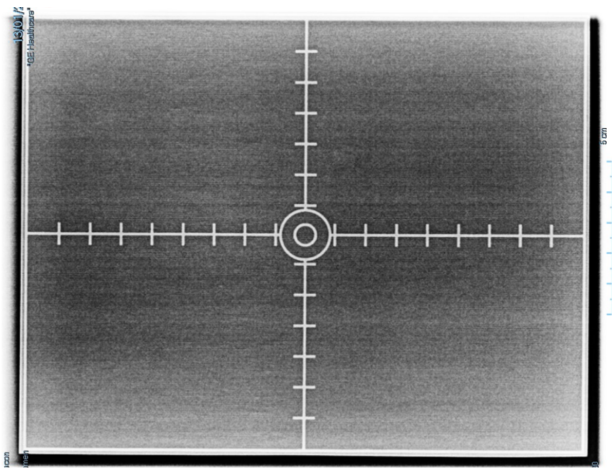

Figure 7: *Image of the guide table developed in this work*

After that, the alignment test device was positioned in the guide table center, and the image acquisition was repeated, in order to evaluate the equipment misalignment. The same test was also performed using commercial devices.

The image of the guide table circles makes the equipment misalignment measurement easier. After image these devices with the alignment test device bottom sphere positioned in the circles center, if the upper one projection is inside the minor circles, it means a misalignment under 1.5°; if it is outside the bigger circles, a misalignment larger than 3° is presented.

It can be seen by comparing the result obtained with the commercial devices, presented in Figure 8, and the result obtained with the devices developed in this work, as shown in Figure 9, that the developed devices produced a useful alignment test image, where both spheres and circles images can be clearly seen. The misalignment measured with the developed devices was relative to 1.5°, the same obtained with the commercial ones. The lattices seen in Figure 9 are the image of the upper and lower surfaces structures of the alignment test device. However, this interference does not affect the beam alignment measurement or evaluation.

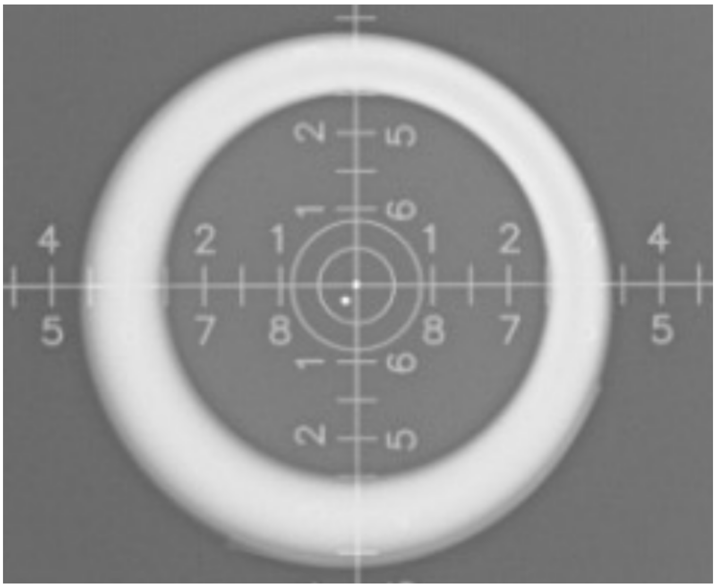

Figure 8: *Alignment test image made with a commercial device and table*

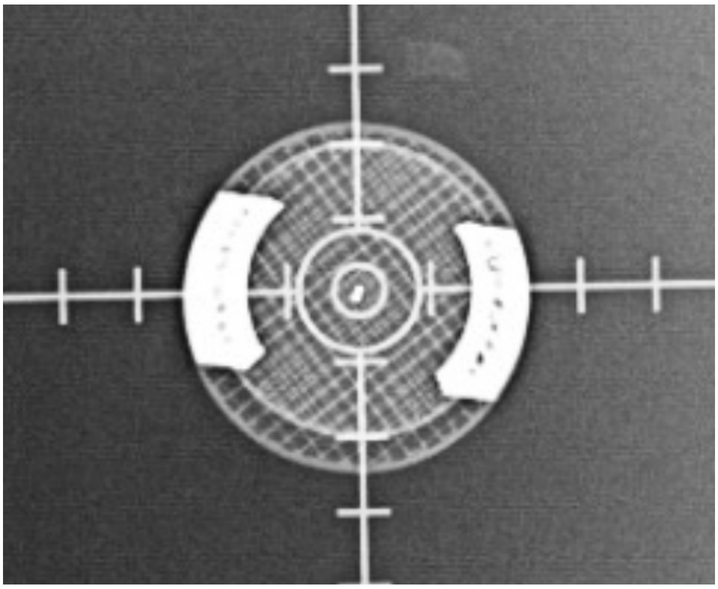

Figure 9: *Alignment test image made with the developed device and table*

4. CONCLUSIONS

In this work, a low-cost alignment test device made with a 3D printer was presented. To perform the measurement and evaluation of a conventional X-ray beam alignment, a guide table was also developed. The results obtained were compared with ones obtained from commercial devices and agree with recommended national standards. Although the image of the alignment test device structure is present, it does not interfere in the analysis of the beam central axis alignment. So, the proposed device can be used to perform the alignment test in conventional radiology equipment.

According to the ANVISA Normative Instruction 90 [2], most of the quality tests needs to be performed annually, with a few exceptions that needs to be perform every six months, the alignment test and the field size test for example. The devices showed in this work are so low-cost and easy to handle, that it can be used by technicians to perform these two tests [9], dispensing the necessity of a six months specialist visit to perform these two tests. This can greatly help small clinics to keep their equipment under recommended national standards.

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