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Development of tools and compliance test of the X-Ray collimator (Dev-X) based on digital image android programming technology

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ABSTRACT

Background

Technological developments, especially in the field of radiology, is growing rapidly. The quality assurance system for radiology equipment has also developed, one of which is the Collimator Test Tools. The method of testing x-ray beams using this tool has also been developed, such as using film and using IP. The development of Collimator Test Tools by utilizing the nature of x-rays which causes certain materials such as calcium tungstate or zinc sulfide to glow light (luminance) has been done a lot, but there is no study of these products. Purpose: The creation of x-ray collimator test tools based on digital image analysis technology (Dev-X), the results of the field measurement of the x-ray beam will match the results of measuring the area of view using the tool. Measure the analog image-based collimator test tool (TOR ABC).

Methods

This type of experimental research, with the posttest group only design type. Research Location at the Radiology Laboratory of the Academy Technique Radiodiagnostic and Radiotherapy (ATRO) Bali.

Results

Functional Test of Dev-X Products (hardware and software), all components function properly. The comparison of the collimator suitability value between Dev-X and TOR ABC products, there is no difference in the results of ΔX, ΔY, and $\Delta X + \Delta Y$ from each tool. However, it cannot be assessed significantly from statistical results.

Conclusion

Hardware and software collimator test tool Dev-X is created and functional on android smartphones and displays the results of the x-ray beam calculation automatically. According to the results of the measurement of the field area of the x-ray beam between the x-ray collimator test tools based on digital image analysis technology (Dev-X) and analog images (TOR ABC) at the Radiology Laboratory of the Academy Technique Radiodiagnostic and Radiotherapy (ATRO) Bali.

Keywords: Quality Control, Collimator Test Tools, Digital Image Processing

INTRODUCTION

The development of radiology technology does not only develop in terms of scientific insight and diagnostic sophistication but in the effort to protect radiation is an important aspect in providing radiation to the minimum possible patient which still needs to be considered in radiological diagnostic services [1]

Radiology equipment is a diagnostic tool needed in diagnosing disease and helping doctors in emergencies, oncologists, and so on. The type of image used to diagnose this disease is a special type of image produced from medical equipment such as USG (Ultrasonography), X-ray, MRI (Magnetic Resonance Imaging), CT (Computed Tomography), PET (Positron emission Tomography). [2]

Compliance with radiation work procedures, radiographic service standards, radiographic examination standard procedures, all of these devices to minimize the level of radiation exposure received by radiation workers, patients, and the environment in which ionizing radiation aircraft are operated [1]

Diagnostic and interventional radiological x-ray equipment used in health facilities must ensure that significant components of the equipment are in proper or reliable condition. The reliable condition means that x-ray aircraft can be operated under specifications and operating limits that ensure the safety of radiation for patients and workers, as regulated in Regulation of the Head of BAPETEN (Nuclear Energy Supervisory Agency) Number 9 of 2011 and has been updated by Regulation of the Head of BAPETEN Number 2 2018, namely regarding the Conformity Test for Diagnostic and Interventional Radiology X-Ray Plates. This regulation regulates and explains explicitly the significant components of equipment that should be tested, the frequency of testing, and the requirements for testing and licensing requirements [3]

The x-ray collimator is one of the significant components that exist in any diagnostic radiology x-ray equipment system including interventional radiology equipment and its reliability must be ensured. Collimators are the most common X-ray limiting device in diagnostic radiology and the most preferred of diaphragms, cones, and cylinders, because of the advantage of collimators is that they can provide a wide variety of rectangular planes and can show the central and precise configuration of the X-ray plane. [4]

Technical efforts to detect early and prevent conditions of mismatch in the function of collimator components, a testing and monitoring program is needed or known as the X-ray Quality Control (QC) Program at health facilities in the Radiodiagnostic section. The Radiodiagnostic x-ray equipment QC program is part of the Quality Assurance (QA) Program, which is in the form of activities to measure the performance of significant components of x-ray equipment quantitatively and continuously so that it can be seen the condition of the equipment's feasibility to be used in radiographic examinations for patients. [5]

Testing to determine the performance of this collimator can be done using various methods, including the collimator test tool designed to evaluate the performance of the collimator (Collimator test tools). Physical parameters evaluate the collimator performance by measuring and calculating the percentage suitability of the coordinates on the abscissa (X) and ordinate (Y), including the percentage of the difference (Δ). The area of the X-ray field must be congruent with the collimator's light field on the abscissa and ordinate sides. Tolerance is declared still appropriate if the percentage of shift X and Y $\leq$ 2%(maximum) of the focus distance to the film plane / Focus Film Distance (FFD) and the percentage ΔX and $\Delta Y \leq 3\%$ of the focus distance to the film plane / Focus Film Distance (FFD) [6]

Collimator test tools have been widely available on the market as testing tools and methods. The Directorate of Engineering and Nuclear Preparedness of BAPETEN issued a product in the form of a sheet of paper with a rectangular image measuring 18 cm x 14 cm in its use, using eight 500 rupiah coins or 1000 rupiah coins which were used as x-ray markers exposed to the receptor image and file calculations. collimations still use manual calculations. Some examples of other testing tools and methods are the RMI Collimator Test Tools and the Gammex 161B Collimator Test Tools. Made of brass, centimeter strokes on its surface can give direct dimensions to a radiograph with normal x-ray exposure. With this test method, the measurement of the field area of the x-ray beam and collimator light still requires x-ray tapes and film or it can also be used on the Imaging Plate (IP) Computer Radiography (CR) or Digital Radiography (DR), where calculations are done still manually with mathematical equations. From an economical point of view, this product is priced at approximately Rp. 9,000,000; depending on foreign currency exchange rates, because this tool is imported from abroad [7]

Testing and measuring the collimator performance without using x-ray film (filmless), namely using an image plate (imaging plate). The measured image (soft file) is evaluated and analyzed with the help of a post-processing computer-based application, on the Computer Radiography (CR) system as an alternative tool without film to assess the suitability of collimators and x-ray beams. However, special image processing expertise is needed in analyzing using this method. (Meechai, Chousangsuntorn, Owasirikul, Mongkolsuk, & Iampa, 2019) As for a more modern, automatic tool with digital technology currently being developed, namely using a digital camera, one of which is a Nova RTI product. The technology used is a webcam with a cable of 10 meters with a maximum recommendation of SSD (Source To Skin Distance) at 75cm and the calculation of the area of the field using a computer programming-based application and the main component as an x-ray beam marker using a phosphorus ruler. The working principle of this tool is a webcam as a phosphor ruler image capture before and after exposure to radiation so that the deviation can be measured between the collimated light beam and the x-ray beam glowing on the phosphor ruler. The image captured by the webcam is opened in special software that is used as a calculation formulation for the deviation of the x-ray beam and collimated light. This product is priced at approximately Rp. 35,000,000; in the sales package. [8]

In the Radiology Laboratory of the Radiodiagnostic and Radiotherapy Engineering Academy (ATRO) Bali, a stationary type of general radiograph has been installed. The radiographic aircraft with the MIS brand model MCR-901R with a maximum rating of 150 kVp was subjected to routine calibration once the last 4 years on 23 February 2017 and quality control assurance was carried out every year using collimator test tools Leeds Test Objects Phantom type TOR ABC made of acrylic blend with a brass grid as a deviation marker with the film screen testing procedure so that the calculation still uses mathematical equations.

According to the Decree of the Minister of Health of the Republic of Indonesia No 1014 of 2008 concerning Radiology Service Standards, the quality control system is done at least once a year (Decree of the Minister of Health of the Republic of Indonesia, 2008) and according to the Decree of the Minister of Health of the Republic of Indonesia No 1250 of 2009 concerning Quality Control Guidelines (Quality Control) Radiodiagnostic equipment that the frequency of the collimator beam similarity test should be done once a month or after repair or maintenance of the tube and collimator housing. The frequency of testing can be multiplied depending on the size of the load on the use of the aircraft. [6]

Therefore, the researcher wants to develop a product with a simpler and more practical concept without reducing the quality of measurement and measurement accuracy of x-ray beams at an affordable cost to achieve a quality control program in an institution that utilizes x-ray aircraft.

Technological developments, especially in the field of radiology, are growing rapidly. The quality assurance system for radiology equipment has also developed, one of which is the Collimator Test Tools. The method of testing x-ray beams using this tool has also been developed such as using film and using IP. However, the development of this method has a drawback, namely that the examiner must have special skills in the post-processing image. The development of Collimator Test Tools by utilizing the nature of x-rays which causes certain substances such as calcium tungstate or zinc sulfide to glow light (luminance) has been done a lot, but there is no study of these products. Therefore, the researcher wants to develop a product by designing the Collimator test tools based on digital image analysis technology (Dev-X) and digital cameras with Android-based calculations on wirelessly connected smartphones as an update of the testing method.

METHOD

This type of experimental research is a true experimental design by developing an existing method by designing and testing the function of the collimator test tool based on digital image analysis technology (Dev-X), with the type of posttest group only design. Research Location at the Radiology Laboratory of the Radiodiagnostic and Radiotherapy Engineering Academy (ATRO) Bali.

RESULT

A. Preliminary Study Stages

At the preliminary study stage, a literature study is carried out, the material for literature study is theoretical material obtained from textbooks, journals, and articles. At this stage, observations of the research location were also carried out in the radiology laboratory of ATRO BALI, to determine the test equipment used in the laboratory and to analyze the development needs to be carried out.

B. Hardware Dev-X

1. Stages of Model Development

At this stage it is divided into three stages, namely:

a. Hardware Design.

1) Designing a laminate sticker in the form of a measurement scale pattern image and which will be affixed to the acrylic and the intensifying screen.
2) Determine the thickness of the acrylic
3) Determine the digital camera that will be used.
4) Determine the thickness of the black sponge foam to be used.
5) Determine the distance to the camera height using a tripod.
6) Determine which tripod to use

b. The materials that will be used include

1) Intensifying screen.
2) Clear acrylic
3) Transparent sticker.
4) Black foam.
5) Double tape.
6) Digital cameras
7) Tripod

c. Dev-X Hardware Assembly.

1) Attaching black foam to the acrylic bottom side
2) Attaching the intensifying screen to the top and bottom acrylic of the acrylic
3) Affix the designed transparent sticker to the intensifying screen.

Figure 1. Hardware Dev-X Prototype Model

1. Stages of Testing the Dev-X (Hardware) Model Function To find out the performance of the tool, it is necessary to do a test. This test is carried out as a benchmark, whether the tool is made to work as expected. The test was carried out at the ATRO Bali radiology laboratory. The Dev-X plate is placed perpendicular to the X-ray tube, set the FFD as high as 100cm then the collimation opening is adjusted according to the mark on the Dev-X plate. 45 kV and mA of 100 were used and the irradiation time was 1s. The action camera is placed parallel to the Y2 axis with a flexible tripod, and the camera tilt is adjusted from 300 to 500 to cover the entire Dev-X plate. The operator is behind the lead screen with a distance of approximately 2.5m.
2. Stages of the Dev-X (Hardware) Model Function Test Results. From these tests, the results on the Dev-X plate functioned well as expected by the researchers, the phosphorus glow from the intensifying screen when exposed to radiation can be recorded properly by the action camera, but to produce maximum luminescence the researchers conducted several trials to ensure conditions. optimal exposure factor. In principle, the exposure factor used is 40-45Kv, 100-125mA with 0.8-2second irradiation time.
3. Stages of Model Validation and Revision The model validation stage is the final stage of this research, where at this stage the final model will be produced. In this stage there are several steps, including the following:
   a) Expert validation is carried out so that the designed hardware can be known for its feasibility based on expert judgment. The research instrument used was a validation sheet. Dev-X validation was carried out by 1 (one) expert, namely Anak Agung Aris Diarthama, S.ST, M. Tr. ID. Experts are experts with radiograph qualifications at ATRO BALI.
   b) Final Revision At this stage, after Dev-X (Hardware) is validated, then a final revision is carried out according to the advice of the expert. In the expert validation step, it is carried out so that the designed Dev-X can find out its feasibility based on expert judgment. Suggestions from experts are in the form of input, namely: In hardware "use of acrylic which on both sides has a risk of bias when reading the results". "The base of the Dev-X plate is better to use soft-touch material so that it provides anti-slip when placed on the examination table" has been refined and adjusted according to the validator's suggestion with the results "suggested revision results have been implemented properly".

Figure 2. The Final Hardware Dev-X Model

C. Software Dev-X

1. Stages of Model Development

a. Software Design

The software is developed using the Android Studio software. Software design through stages, namely:

1) Designing the layout from the display on the smartphone
2) Determine the sequence of digital image processing that will be used
3) Designing the x-ray deviation calculation formulation
4) Coding software on Android Studio.
5) Perform software rendering
6) Installing software on a smartphone
7) Perform software testing.

b. Dev-X Software.

The Dev-X software is developed through the Android Studio computer software which contains image processing and calculation of x-ray files. The process before entering a video file into a smartphone, the user must download the video recording from the action camera to the smartphone via wifi connectivity.

Figure 3. Dev-X icon

1) Video to Image Grabbing.

A technique to take the desired image in video data. The image obtained is the most informative selected image in the video.

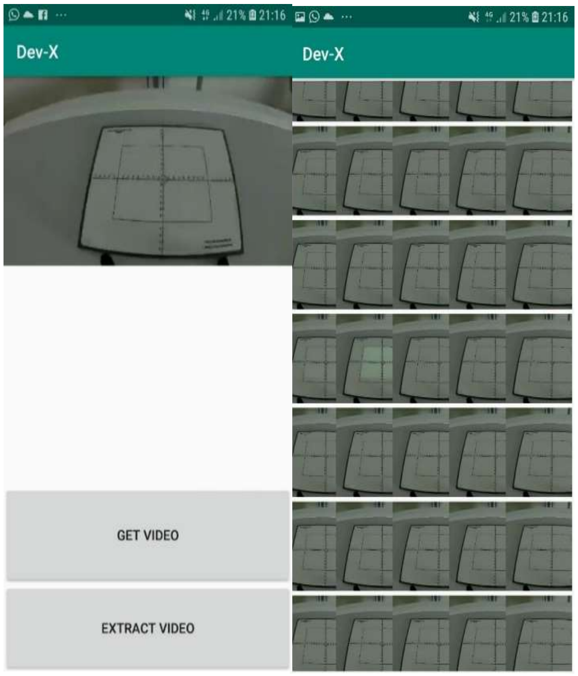

Figure 4.ScreenShoot Video to Image Grabbing Dev-X

2) Image Transformation.

This technique is a 2-dimensional digital image processing technique using mathematical methods with the concept of a side view into a viewpoint from above.

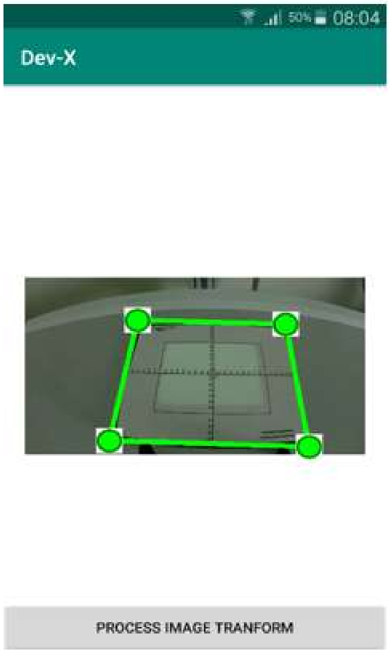

Figure 5. ScreenShoot Image Transformation

3) X-ray beam deviation calculation system.

Contains a mathematical formula for calculating the x-ray beam deviation. With the collimation field deviation test formula with the radiation field is $X1 + X2 \leq 2\%$ of FFD and $Y1 + Y2 \leq 2\%$ of FFD or $\Delta X + \Delta Y \leq 3\%$.

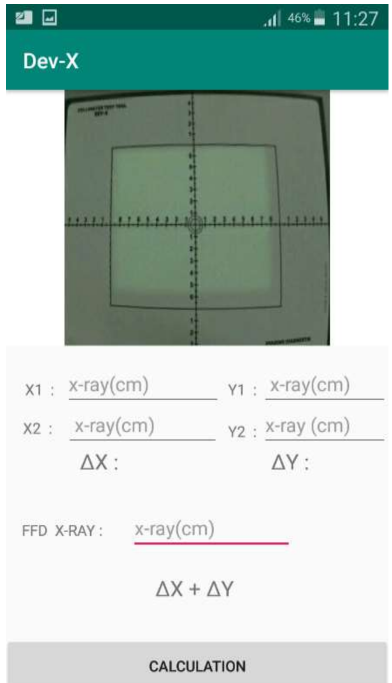

Figure 6. ScreenShoot of Android-Based Deviation Calculation System.

2. Stages of Testing the Dev-X (Software) Model Functions.

To find out the performance of the tool, it is necessary to do a test. This test is carried out as a benchmark, whether the tool is made to work as expected. The test was carried out at the ATRO Bali radiology laboratory. The Dev-X software is installed on the Samsung A5 2013 smartphone with the Android version 6.0.1 (Marshmallow).

3. Stages of the Dev-X (Software) Model Function Test Results.

The Dev-X software functions as data processing and calculation of x-ray deviation, first the video that has been taken from the camera source through the default application of the action camera is then inputted in the Dev-X software then extracted into an image according to the number of image frames contained in the entire duration of the video, then the user selects an informative image as the test data, after the determined image the researcher inserts an image processing technique to clarify the reading of the results with a transformation perspective technique, then at the calculation stage by evaluating the image and inputting the data according to the specified column. The results that come out are Fail or Pass, fail means the collimator tested exceeds the recommended standard deviation, a pass means the collimator tested is in a state of normal limits.

4. Stages of Model Validation and Revision

The model validation stage is the final stage of this research, where at this stage the final model will be produced. In this stage there are several steps, including the following:

a) Expert validation

Expert validation is carried out so that the feasibility of the designed hardware and software can be determined based on expert judgment. The research instrument used was a validation sheet. Expert validation of Android Dev-X software was chosen by a lecturer from STIMIK Primakara 1 (one) expert on biomedical engineering, machine learning, and image processing, namely I Putu Satwika, S. Kom., M. Kom.

b) Final Revision

At this stage, after Dev-X (Software) is validated, then a final revision is carried out according to the advice of the expert. In the expert validation step, it is carried out so that the designed Dev-X can find out its feasibility based on expert judgment. Advice from experts is in the form of input, namely: In the software, namely "Split video with a timeframe that is too small causing the application to experience a force close". "The image perspective transformation has a small size, needs to be enlarged to facilitate object recognition" has been adjusted according to the validation results "validated that the given revision has been corrected and the application is running well".

D. Field Trials

Field trials were carried out at the ATRO Bali radiology laboratory on an X-ray aircraft brand Medical Instrument System (Toshiba) Type E7239 with serial number 6H0878, max conditions 125kV and 300mA. Collimator model MCM-901R, SER.No1611042 with the specification of permanent filtration1.1mm Al.Eq. Field trials in this study are divided into 2, namely product functional tests and product performance tests.

Figure 7. Dev-X Testing.

The product functional test aims to assess the work capability of the component system of the Dev-X product which is carried out by qualified experts, including the functions of the Dev-X plate component system, Action camera, and Dev-X Software developed based on Android OS on smartphones. The results of the function test of this component system shown in table 1 of the Dev-X Product Functional Test.

Table 1:Dev-X Product Functional Test.

No	Tool	Fungsi		Keterangan
		Yes	No	
1	Plat Dev-X	√		Glows phosphor light
2	Camera	√		Capable of Capturing the glow of the intensifying screen.
3	Software	√		Function well.

In table 1. Functional Test of Dev-X Products, it can be seen that all components are functioning properly and can function as expected. On the Dev-X plate, the intensifying screen component can emit phosphor light. The camera can capture images when the intensifying screen shines phosphor light and can evaluate the image through a measurement scale attached to a clear sticker on the surface of the intensifying screen. And the digital image processing technique software embedded in the software (image grabbing, image transformation, and mathematical formulas for calculating x-ray deviation) can function properly.

Meanwhile, the product performance test aims to measure the performance of the product in producing the measured value of the collimator performance measurement parameters (X, Y; ΔX, ΔY, and ΔX + ΔY).

The results of observations from measurements using the two methods are as described in tables 2 and 3, and for the next, the value of the Dev-X collimator suitability parameter is compared with the value of the TOR ABC gold standard measuring instrument (gold standard), as in tables 2, 3 and 4.

Table 2. The test results of the x-ray beam measurement for the collimator model MCM-901R, SER.No1611042 using the Dev-x test tool in centimeters.

n	Dev-X Collimator Test Tool (cm)						
	$X1_{dev}$	$X2_{dev}$	ΔX_{dev}	$Y1_{dev}$	$Y2_{dev}$	ΔY_{dev}	$\Delta X+\Delta Y_{dev}$
1	9	8	1	7	5.7	1.3	2.3
2	9	8	1	7	5.7	1.3	2.3
3	9	8	1	7	5.7	1.3	2.3
$\bar{\chi}$	0	1	1	0	1.3	1.3	2.3
SD	2	2	≤ 2%	2	2	≤ 2%	3 ≤ 3%

In table 2 it can be seen that the results of the x-ray beam measurements carried out are the difference in the x-ray beam with a total deviation of ΔXdev ≤ 2% FFD, namely 1cm and on the sumbuYdev ≤ 2% FFD axis of 1.3cm, which means that the x-ray plane collimator in radiology laboratory ATRO Bali uses Dev-X within normal limits, seen from the image on the X2dev and Y2dev axes, it is necessary to recalibrate to minimize the deviation on these axes.

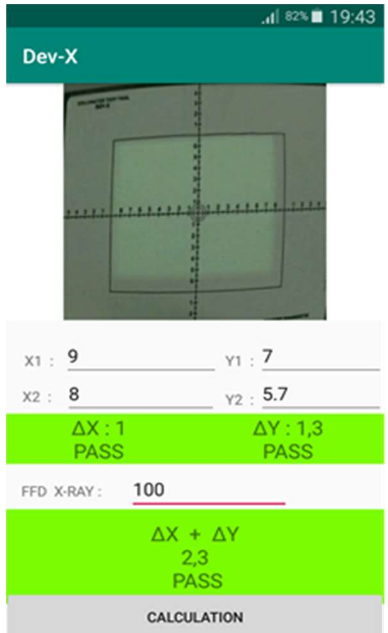

Figure 8 is a screenshot taken from a smartphone screen based on the Android OS on the Dev-X software.

Table 3. The test results of the x-ray beam measurement of the collimator model MCM-901R, SER.No1611042 using the TOR ABC test (gold standard).

n	TOR ABC Collimator Test Tool (cm)						
	$X1_{tor}$	$X2_{tor}$	ΔX_{tor}	$Y1_{tor}$	$Y2_{tor}$	ΔY_{tor}	$\Delta X+\Delta Y_{tor}$
1	9	8	1	7	5.7	1.3	2.3
2	9	8	1	7	5.7	1.3	2.3
3	9	8	1	7	5.7	1.3	2.3
$\bar{\chi}$	0	1	1	0	1.3	1.3	2.3
SD	2	2	≤ 2%	2	2	≤ 2%	3 ≤ 3%

In table 3, it can be seen that the results of the x-ray beam measurements carried out are the difference in the x-ray beam with a total deviation of ΔXtor ≤ 2% FFD which is 1cm and on the ΔYtor ≤ 2% FFD axis of 1.3cm which means the collimator of the x-ray plane in radiology laboratory ATRO Bali uses TOR ABC within normal limits, seen from the image on the X2tor and Y2tor axes, it is necessary to recalibrate to minimize the deviation on that axis.

Table 4. The comparison of the collimator suitability values between Dev-X and TOR ABC products refers to Perka Bapeten No. 2/2018 for the measurement distance (FFD) of 100 cm

Collimator Suitability Parameters	Dev-X	TOR ABC	% diff	Conformity Fulfillment
	$\bar{\chi}$ (cm)			
ΔX≤ 2% (2 cm)	1	1	0%	suitable
ΔY≤ 2% (2 cm)	1.3	1.3	0%	suitable
ΔX+ΔY≤ 3% (3 cm)	2.3	2.3	0%	suitable

Judging from table 4 The comparison of the collimator suitability value between Dev-X products with TOR ABC at nilaiX ≤ 2% (2 cm) both gives a suitability value ≤ 2% (2 cm) on FFD as well as at ΔY ≤ 2% (2 cm). The value of ΔX + ΔY≤ 3% (3 cm) on FFD between Dev-X products with TOR ABC of 2.3 cm or ≤ 3% (3 cm) on FFD. All results show 0% there is no difference in the results of ΔX, ΔY, and ΔX + ΔY from each tool. However, it cannot be assessed significantly from statistical results.

DISCUSSION

1. Stages of Preliminary Study

The advantage of Dev-X is that it is a tool developed from the principle of an intensifying screen that can emit phosphorus light. The researchers used the phosphorus light as an x-ray beam marker and as a film substitute in analog image-based testing. Dev-X is said to be a collimator test tool based on digital image technology analysis because the phosphorus light that is driving is recorded by the action camera. The results of the video recordings are processed using Dev-X software so that the output of the test is a digital image and measurement data of the difference in x-ray beams. The X-ray beam testing system in the Dev-X software suggests semi-automatic testing, users no longer need to calculate using mathematical formulas like testing using analog images. Another advantage of Dev-X is that it is more practical and simple to use but does not reduce the quality of the test and the accuracy of the test results.

2. Model Development Stage

Dev-X consists of hardware and software, Dev-X hardware is made of acrylic material as an intensifying screen adhesive medium coated with a transparent sticker as a scale marking x-ray beam, then the base of Dev-X is in the form of black foam as an anti-slip. Acrylic is used with a thickness of 4mm which aims to make the intensifying screen a glue and produce a stiff impression. Because the acrylic is slippery so it needs to be given black foam as an anti-slip when placed. The action camera is used because it has 4k video recording quality at 60fps, so the hope is that it will be able to capture phosphorus luminescence images on the intensifying screen. Action camera used with the brand and type B-Pro 5 ES Mark IIs. The weakness of this hardware is that the resistance level of each material used has not been tested. The weakness of the Dev-X plate is that the use of automatic exposure control cannot maximize phosphorus glow. In terms of capturing images, the action camera is good at capturing these images.

Dev-X software was developed using an android studio. This software has the function of image processing and x-ray data processing to be measured, where generally the conventional collimator testing uses physical film and mathematical equations to measure the difference in x-ray beams, so hopefully with this software experts in the field of quality control make it easier. In the operation, the officer only evaluates X1, X2, Y1, Y2 ΔX + ΔY then center the FFD according to the test carried out then just press the result button and the result of the difference in the x-ray beam will appear Pass or Fail. This software was developed to be applied on smartphones so that it has the advantage of being simpler and more practical to carry, making it easier for users to mobilize. The weakness of the software is the possibility of force close when the video recording file is more than 5 seconds long.

CONCLUSION

1. The creation of the Dev-X collimator test tool hardware with intensifying screen, clear acrylic, transparent stickers with measurement scale, black foam, B-Pro action camera, and tripod and the creation of the Dev-X collimator test tool software on an android smartphone to perform image processing (Image Grabbing, Image Transformation) and display the results of the x-ray beam calculation automatically.
2. The functioning of the hardware and software collimator test tool Dev-X and displays being able to display the results of x-ray beam calculations automatically.
3. Adjustment of the results of the field measurement of the x-ray beam between the collimator test tools for x-ray aircraft based on digital image analysis technology (Dev-X) and analog images (TOR ABC) at the Radiology Laboratory of the Radiodiagnostic and Radiotherapy Technique Academy (ATRO) Bali.

From the results of research and discussion, it can be suggested that:

1. There needs to be further research on the material quality of the Dev-X hardware.
2. There needs to be a development of the software to minimize force close.
3. Need for further research and testing with more varied samples and test variations

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