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Implementation of Quality Control Tests for two Digital X-Ray Equipment in Riyadh

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ABSTRACT

The main aim of diagnostic radiology is to deliver high-quality diagnostic image information regarding anatomic detail or an ongoing physiological process within a patient's body, when such information cannot be provided by an alternate diagnostic method that does not require ionizing radiation. The major purpose of the quality assurance (QA) program of radiological practice optimization is to ensure enough clinical diagnostic information while exposing the patient to the least amount of radiation possible (as low as reasonably achievable ALARA principle) at the lowest cost. Implementing the QA program entails more than just completing legal requirements for quality control (QC) of X-ray and associated equipment and the regions where they are installed; it also entails making the best use of equipment, human, and material resources, as well as patient dosage monitoring during articular radiographic diagnostic procedures. The main objective of this study was to perform QC tests on stationary radiographic X-ray machines, installed in two hospitals of Riyadh city, Saudi Arabia. Based on the findings, kVp accuracy, kVp reproducibility, timer accuracy, timer reproducibility, exposure reproducibility, mA/timer linearity, and half-value layer were within the acceptable limits. Thus the result of the two X-Ray machines passed all the QC tests.

Keywords: Diagnostic X-ray, Quality Assurance, Quality Control, X-ray meter, Radiology Device

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INTRODUCTION

The goal of Quality Assurance (QA) testing is to offer the greatest possible image quality while limiting the amount of radiation that the patient is exposed to. QA tests are required to calibrate all exposure parameters, assess the functional performance of X-ray equipment, and ensure radiation safety around the X-ray installation. Routine quality control (QC) tests are required to guarantee that the equipment's functional performance is similar to its baseline values and within the tolerance values defined by the regulatory body. These tests should be carried out at the user institution by qualified service engineers. These examinations should be carried out on a regular basis (once every year) and at the time of major repairs to X-ray equipment [1].

Table 1: Quality Control Tests in the first measurements at King Saud Medical City in Riyadh

1.	kVp Accuracy & Reproducibility	4. mAs Reproducibility
2.	Exposure Time Accuracy & Reproducibility	5. Beam Quality HVL
3.	mAs Linearity	6. Image Quality

MATERIALS AND METHOD

All the QC tests carried out in this work was based on RaySafe base unit. This is because such device is an active dosimetry system that provides real-time insights about radiation exposure. Thus, helping medical staff and physicians evaluate and take action to more effectively use all the radiation reduction solutions provided in the room. Several QC tests of X-ray machines were carried out in two different radiology departments over the course of two different measurement, with the assistance of medical physics supervisors. The first part of this work took place on Monday, March 14th, 2022, at King Saud Medical City in Riyadh (see Table 1), and the second part of this work were carried out on Tuesday, March 15th, 2022, at Rafa Medical Center in Riyadh as demonstrated on Table 2. The Piranha MULTI X-ray meter is the one used for qualified diagnostics and QA on Rad/Fluoro, CT, Dental, and Mammography X-ray scans. This is because such meter can measures kVp, Time, HVL, Total Filtration, Dose, Dose rate, presents Waveform, and much more. It is really an all-in-one multifunction meter. Connect to computer wireless or via USB for a complete QA system.

Table 2: Quality Control Tests in the second measurements at Rafa Medical Center in Riyadh

1.	Tube voltage reproducibility	4.	Tube Voltage Accuracy
2.	Exposure reproducibility	5.	mAs linearity
3.	Exposure time reproducibility	6.	Half Value Layer

RESULTS AND DISCUSSION

X-rays play an important role in modern technology, particularly in medical imaging. Introduction QC techniques are used in monitoring and maintenance of the components of an X-ray system. The QC of radiology equipment plays a significant role in reducing the medical radiation dose to the patient and optimizing the image quality. This study aimed to conduct QC tests on two randomly selected X-ray devices, installed on diagnostic imaging in diagnostic imaging departments of King Saud Medical City in Riyadh.

Figure 1: RaySafe X2 Base Unit. This is an X-Ray QA measurement system was used to cover all measurement. Such tests equipment was used in the first work [2].

Figure 2: RaySafe X2 R/F multi-parameter sensor (a silicon diode-based sensor).

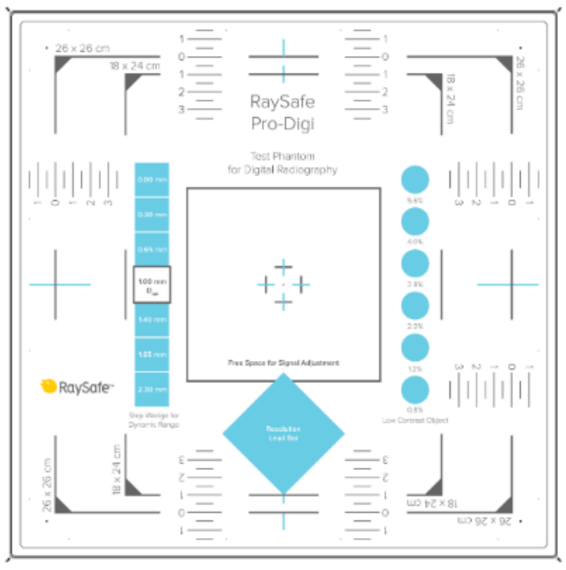

Figure 3: RaySafe Pro-Digi Test Phantom for digital radiography.

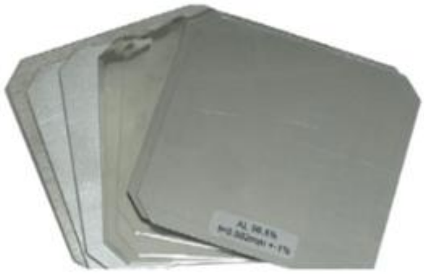

Figure 4: Aluminum (Al) half value layers (HVL) filter kits for traditional HVL measurement. The Al 99,0 % purity, and the kit can be used in both mammography and radiography and comes in two different sizes i.e. 90×90 mm 99.5% Al filter set (1 pc 2 mm, 2 pcs 1 mm, 2 pcs 0.5 mm)

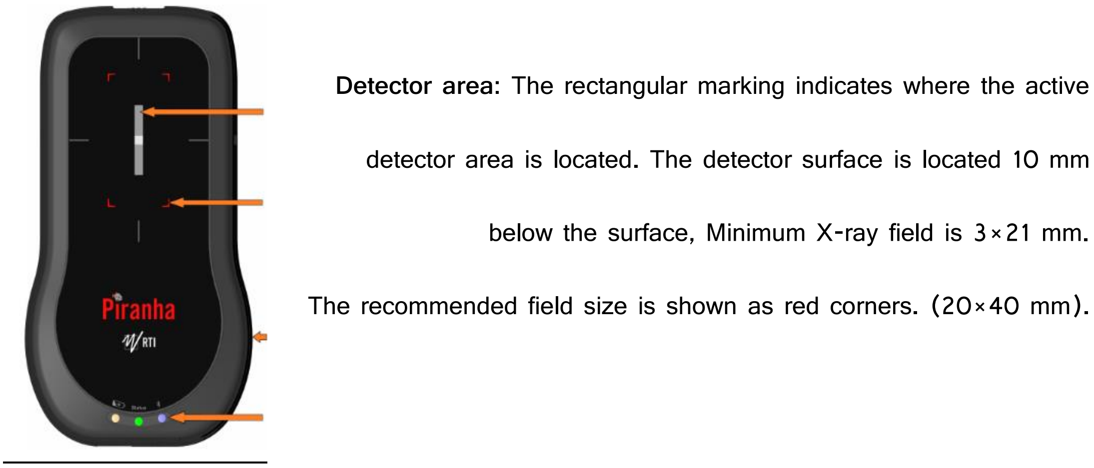

Figure 5: The Piranha meter [5]. Such X-ray tests meter was the one used in the second work.

Table 3: This table outline the X-ray machine information of the first work carried out.

Department/ Room:	**Radiology department/pediatric X-ray room**	**Tube Type:**	**RAD-60**
Manufacture:	Varex Imaging	Insert Serial No.	48728-1V

kVp Accuracy & Reproducibility Test:

Kilovolt peak (kVp) is a technical factor set by the technologist when performing X-rays. Its purpose is to set the penetrating power of the X-rays or the quality of the beam. The number set is the highest amount of energy that an X-ray photon could have leaving the tube. It is important that the kVp setting reflects what is actually coming out of the tube to ensure reproducibility [[6]]. kVp reproducibility test was performed on both X-ray units, to measure the ability of the X-ray generator to faithfully deliver the same output when the same exposure factors are used, 3 consecutive measurements at the same SID of 100 cm, and fixed mAs of 20 and a fixed kVp. The procedure of measurements were fairly simple. We set the SID to 100 cm and collimated to the entirety of the sensor. We took six exposures each at 60 kVp, 81 kVp, and 125 kVp at 20 mAs. Three of these measurement were with small focal spot size and the rest with large focal spot [9].

The QC procedures require that the X-ray tube voltage variation be within ±4 kVp or ±5% of the normal value, whichever is less, within 150 mS of initiating the exposure, assuming that the equipment is operating in a stable manner [10]. As per the American Association of Physicists in Medicine (AAPM) guidelines, the acceptable limit of the percentage of variation in kVp accuracy is ± 5% and hence the two X-ray machines passed the kVp accuracy tests. There are guidelines set by Healing Arts Radiation Protection (H.A.R.P) and safety code (S.C) 35 to ensure an appropriate range of kVp accuracy. The H.A.R.P) sets the accuracy at ±8% while S.C. 35 sets it at ±10% while the most strict sets with ±5% [11]. In room 4, all kVp settings pass. In room 3, 60 kVp at 5 mAs and 60 kVp at 16 mAs fail by all standards. Some possible reasons for this are that the reader was less sensitive to this lower kVp setting, the unit has faulty circuitry, the high voltage transformer may be malfunctioning, the autotransformer may have an issue, or the supply to the generator is not the greatest [12]. It is very important that kVp accuracy is maintained to ensure that the desired technique is coming out of the tube. Since kVp controls both x-ray beam quality and quantity, having the incorrect kVp exiting the tube may result in failing to follow the ALARA principle and overdosing our patient. This test should be performed annually [11]. We took another three exposures each at the aforementioned kVp but at 16 mAs. We used the X-ray meter to determine the kVp values and a different meter for confirmation. When we took these exposures, we waited roughly 30 seconds between each exposure to prevent tube overload.

Table 4: Outlined the kVp Accuracy & Reproducibility Test. All results are within the acceptable limit.

Set kVp	Set mAs: 20 , SID: 100 cm , Small Focal Spot			Set mAs: 20 , SID: 100 cm , large Focal Spot		
60	60.3	60.2	60.5	60.2	60.1	60.3
81	81.5	81.5	81.7	81.2	81.2	81.3
125	127.7	127.6	127.5	126.9	127.1	127.1

For the reproducibility of kVp the machine was set up to 20 mAs. For example, the kVp was set to 60 and noted down the readings of kV. The same procedure was repeated for the voltage of 60 to find the reproducibility of kVp. Kilo voltages Reproducibility Should be ≤ ±5%. For set up of 60 kVp and small focal spot the Coefficient of variation (Eq. 1) was 0.2533% and the limit is 10%. The mean value is 60.33 and its standard deviation was 0.1528 kVp. On the other hand for the kVp accuracy test the Max. Inaccuracy should be ≤ ±5% and based on Eq. 2 the percentage of kVp error was 2.16%.

$$\text{Coefficient of Variation} = \frac{\text{Standard Deviation}}{\text{Avarage}} \times 100 \qquad \text{(Eq. 1)}$$

$$\text{Coefficient of Variation} = \frac{0.1528}{60.33} \times 100 = 0.2533\ \%\ (\leq\ \pm 5\%\ )$$

It is important that the kVp setting reflects what is actually coming out of the tube to ensure reproducibility. To insure this we use Eq. 2 to calculate the percentage kV error.

$$\text{Percentage kVp error} = \frac{(\text{V0} - \text{Vs})}{\text{Vs}} \times 100 \qquad \text{(Eq. 2)}$$

$$\text{Percentage kVp error} = \frac{(127.7 - 125)}{125} \times 100 = 2.16\ \% \ (\leq \ \pm 5\%)$$

Exposure Time Accuracy & Reproducibility Test

Exposure timer. Allows the electrons to flow from the cathode to the anode for a specific period of time. it is located on the primary side of the high voltage transformer. Exposure time calculation in radiography is very important to perform radiography tests and develop radiographs meeting the standard requirements. Exposure time is the time required for sufficient radiation energy to ionize the film emulsion to the desired density after processing. According to S.C. 35, the actual time of exposure should be within ± 10% + 1 mS of the time selected by the operator. Similarly, according to the H.A.R.P Act, the actual time can deviate from the selected time by no more than ± 10%. There are many variables that affect the final radiograph. Some of the variables that affect the density of the radiograph include: the spectrum of radiation produced by the X-ray generator; the voltage potential used to generate the X-rays (KeV); the amperage used to generate the X-rays (mA); the exposure time and the distance between the radiation source and the imaging detector. Table 5 outlined the Exposure Time Accuracy and Reproducibility Tests carried out in this study.

Table 5: Exposure Time Accuracy & Reproducibility Tests, [6, 9]. All results are within the acceptable limit. Note that the results of the Exposure Time are from the calibration tool reading.

Set mS	Set mAs: 20 , Set kVp:81 , SID: 100 cm , Small Focal Spot			Set mAs: 20 , Set kVp:81 , SID: 100 cm , Large Focal Spot		
25	25.2	25.2	25.1	25.1	25.1	25.1
50	49.9	49.8	49.8	50	50	49.9
200	200.1	200.1	200.2	200.2	200.2	200.1

For the reproducibility of mS the machine was set up to 20 mAs. For example, the mS was set to 25 and noted down the readings of mS The same procedure was repeated for the mS of 25 to find the reproducibility of the mS first the machine was set at 25 mS using small focal spot size and the coefficient of variation was calculated and found to be 0.23% (i.e. less than the limit which is 10%). The mean value was 25.16 and the standard deviation was 0.0583 mS and based on Eq. 3 the time accuracy passed the test (0.25%) as the coefficient of variation found to be less than 5%. For the mS accuracy test the Exposure Time Accuracy test should be within ±5% (for times greater than 10 mSec) and ±10% for times less than 10 mSec as demonstrated in Eq.4.

$$\text{Coefficient of Variation} = \frac{\text{Standard Deviation}}{\text{Avarage}} \times 100 \qquad \text{(E.q. 3)}$$

$$\text{Coefficient of Variation} = \frac{0.0583}{25.16} \times 100 = 0.23\ \%\ (\mathit{less\ than}\ 5\%)$$

$$\text{Percentage timer error} = \frac{(\text{T0} - \text{Ts})}{\text{Ts}} \times 100 \qquad \text{(E.q. 4)}$$

$$\text{Percentage timer error} = \frac{(25.2 - 25)}{25} \times 100 = 0.8\%\ (\text{within } \pm 5\%)$$

mAs Linearity & Reproducibility Test

One of the main radiography QC tests is mAs linearity and this mean the production of a constant amount of radiation for different combinations of milliamperage and exposure time. In the clinical setting, it is essential that all general X-ray units produce a proportional change in exposure as milliamperage (mA) varies. The assumption is that an increase in mAs, should produce proportional increases in radiation exposure. The set up factor for mAs Linearity and Reproducibility Test was given in table 6.

Table 6: mAs Linearity & Reproducibility Test

Set kVp	SID	Focal Spot
81	100 cm	Small Focal Spot

Table 7 The exposure measurements. All results are within the acceptable limit

Set mAs	Exposure (mGy)			Average	mGy/mAs
5	0.2901	0.2912	0.2923	0.291	0.0582
10	0.5632	0.5686	0.5672	0.566	0.0566
20	1.142	1.143	1.144	1.143	0.0571
40	2.302	2.286	2.299	2.296	0.0567
80	4.576	4.566	4.555	4.566	0.0570

For the Reproducibility of mAs measurement the coefficient of variation within accepted limit. Here the results are the exposure (mGy) from the calibration tool reading. For the mAs Linearity the obtained result of the mAs Linearity Test i.e. the mR/mAs should be <±10%. As demonstrated in table 7, the maximum difference in mGy/mAs between adjacent stations was found to be 0.2 % (0.058-0.056=0.2%) and this was below the limit which is 10%. As we increase mAs the dose will increase i.e. there is a Positive relationship between the mAs and the dose. To determine if the X-ray unit produces the same radiation output linearity for the same kVp and mAs regardless of the mA station used. This was obtained by calculating the mAs Linearity test as demonstrated in Figure 6.

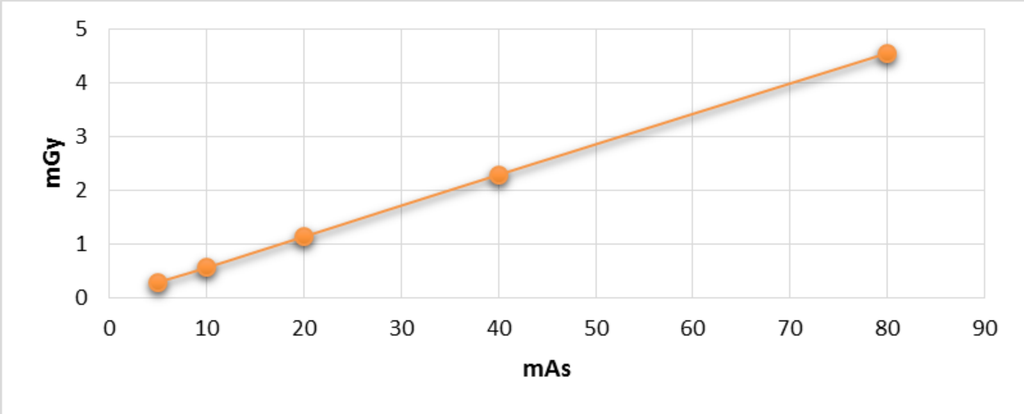

Figure 6: The mAs Linearity test._According to H.A.R.P., the average mR/mAs should not differ by any more than 0.10 times their sum and the result totally agree.

Beam Quality HVL Test

Beam Quality describes the shape of the energy spectrum (i.e. the energy distribution of the x-rays) and beam quantity describes the total intensity of the spectrum (i.e. the area under the x-ray spectrum curve). The factors affecting beam quality including: kVp, target material, and pre-patient collimation. We also discuss the mA (tube current) which is the most important factor that affects only the beam quantity and not beam quality [3, 4, 6]. Beam quality describes the shape of the x-ray spectrum. So we will review X-ray spectrum briefly here. The X-rays coming out of our clinical X-ray tubes are not all one energy. That would be called monoenergetic or monochromatic. We have a separate post where we describe the physical mechanisms which responsible for x-ray generation. For more details please see that post if you aren't familiar with the general shape of the X-ray spectrum.

At a high level the x-ray spectrum is a plot of the Number of X-ray Photons (y-axis) as a function of the energy level in keV (x-axis). As we describe in the x-ray generation post the highest energy in an X-ray spectrum is determined by the kVp. The lowest energy photons are typically filtered out by the internal filtration. The peaks in the spectrum are due to characteristic radiation and only contribute a small amount to the total number of photons. In the remaining sections of the post we will discuss: why we are interesting in beam quality, what affects beam quality and finally how to measure beam quality. In the section on factors that affect beam quality we will spend some time on the difference between beam quality and beam quantity. We also want to differentiate beam quantity from beam quality where changes in beam quantity may occur without changes in beam quality. Changes in beam quantity mean that the shape of the curve remains the same but there are more or less x-ray photons. The most common way that the beam quantity is changed is via changing the mA (tube current). Beam Quality describes the shape of the spectrum and on the other hand Beam Quantity describes the number of X-rays and beam quantity can be changed without changing the shape, for instance by changing the mA [7, 9]. As demonstrated in table 9, the HVL Test performed to determine if there is enough radiation produced by an individual system, to actually produce a quality diagnostic image, while not exposing a patient to more radiation than is necessary.

Table 8: Beam Quality HVL Test set up parameters used for the first X-ray machine outlined in table 1.

Set kVp	Set mAs	SID	Focal Spot
81	20	100 cm	Large Focal Spot

Table 9: The HVL Test performed to measure the quality or intensity of the beam. The result is an indirect measure of photon energy or beam hardness.

Al Thickness (mm)	0	0.5	1	2	3	4
Exposure (mGy)	0.8898	0.8005	0.7183	0.5892	0.4956	0.423

Half-value layer (HVL): is the width of a material required to reduce the air Kerma of an x-ray or gamma-ray to half its original value. The methods for such measurements the machine was set up to 81 kVp and 20 mAs. The X-ray test device was placed 100cm away from the focal spot. X rays were exposed to test device without Al filter and the reading was noted down. Then the Al sheets with different thicknesses were added one by one, and the readings were taken to find out HVL. The beam quality HVL for X-ray generator limits is ≥ 2.5 mm. The calculated value is greater than the accepted value for a specific value of kVp. The HVL = 0.693 / μ => HVL = 3.284 mm. Another way to calculate HVL is (0.8898 ÷ 2 = 0.4449), so the HVL is between 3 and 4 mm. For the measurements with the R/F sensor we place the connected sensor centered in the field with the crosshair towards the X-ray source. The angle of the sensor in the horizontal plane has no impact on the measurement result. Then perform the exposure and directly read the result.

Image Quality Test

Three physical factors determine the quality of radiography, contrast, sharpness and quantum noise. Contrast refers to the density difference between the areas of the radiograph, which allows the display of information contained [3, 9]. Test for a variety of image quality factors at once using over 30 popular test charts. Test everything from sharpness, distortion, color, illumination and more. The details of set up and results was outlined in table 10.

Table 10: Image Quality Test in this study the kVp was 81, the mAs was 20 and the SID was 100 cm using large focal spot size.

1- Dynamic range	6 different shades of gray were visible.
2- Spatial resolution	2.5

3- Contrast resolution	All 6 low contrast objects was visible and did not change over time.
4- Collimator light field and beam alignment	The sum of differences between the light and the X-ray field in each direction is less than 2% of the FDD (focal spot to detector distance) **Results:** (a1= 0, a2= -0.25, b1= 0.25, b2=0.75) $\lvert a1\rvert + \lvert a2\rvert \leq 0.02 \times FDD$ $\lvert b1\rvert + \lvert b2\rvert \leq 0.02 \times FDD$

The RaySafe Pro-Digi Radiography Phantom (See Figure 8) is a multi-functional phantom designed for digital radiography equipment constancy tests. It is used for analyzing beam alignment, dynamic range, contrast resolution, spatial resolution, and homogeneity. The versatile phantom enables you to bring only this phantom for image quality checks. This phantom also reduces the amount of exposure and time spent while performing the required tests. The procedure for this test is to place the Pro-Digi phantom on the table and then set the distance between the focal spot and the detector (FDD) to at least 1 m. At this stage you need to make a note of the FDD and position the phantom so its center and main axis align with the light marker of the apparatus. Then narrow the light field (which should represent the X-ray field) to the chosen markings on the phantom. Now make the exposure and you can use automatic or manual mode to produce desired contrast and the final images can be seen on Figure 9 and Figure 10 respectively.

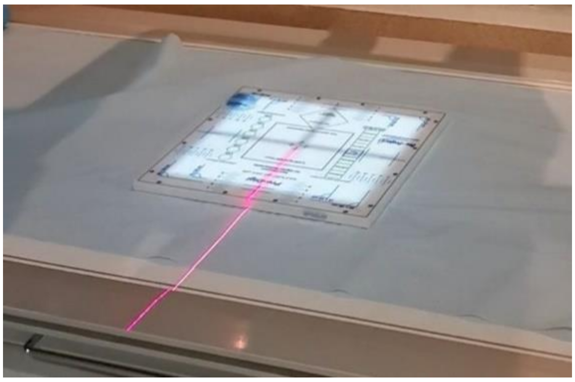

Figure 8: A photo of the RaySafe Pro-Digi Radiography Phantom.

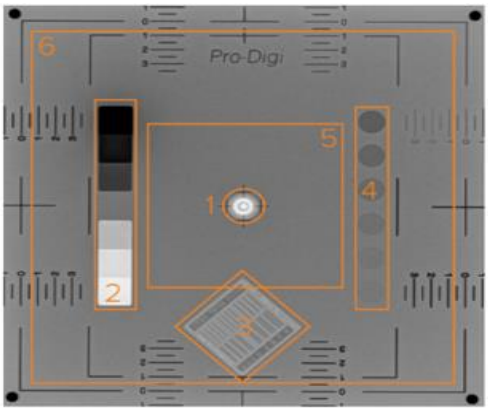

Figure 9: X-ray image of the phantom, with test structures: 1: Central beam alignment, 2: Dynamic range, 3: Spatial resolution, 4: Contrast resolution, 5: Homogeneity, 6: Collimator light field and beam alignment.

Figure 10: Dynamic range and all seven different shades of gray were visible

Spatial Resolution Test

Spatial resolution is one of the most important characteristics that reflect the details of an image. The spatial resolution of an X-ray system is a measure of the ability of a system to differentiate small structures. If you imagine imaging a very small point like object an image of that object is called the Point Spread Function (PSF). In other words, by assessing the spatial resolution of the system, the image quality can then be monitored. Spatial resolution refers to the ability to differentiate separate objects of high subject contrast that are adjacent to one another. Spatial frequency, another fundamental concept of radiography, is typically measured in line pairs per millimeter (lp/mm) see Figure 11. Spatial frequency is related to spatial resolution; to be more specific, higher spatial frequency allows higher spatial resolution.

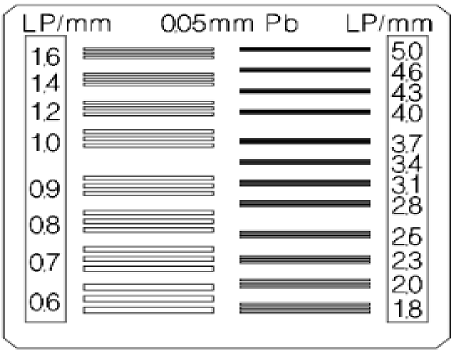

Figure 11: Spatial Resolution for analyzing this test the zoom tool was used on a workstation to determine the line pairs per millimeter resolution. You should be able to distinguish three separate lines.

Contrast Resolution

Contrast resolution in radiology refers to the ability of any imaging modality to distinguish between differences in image intensity. The inherent contrast resolution of a digital image is given by the number of possible pixel values, and is defined as the number of bits per pixel value. Higher energy beams cause greater X-ray penetration, less degree of attenuation by the tissues, and more scatter radiation. [5] This results in lower contrast and lower dose. Figure 12 demonstrate the ability of the tested X-ray imaging system to distinguish between differences in image intensity.

Figure 12: The contrast resolution test. The high contrast resolution should not change over time and should be within the values used in the resolution lead bar. All six low contrast objects should be visible and should not change over time.

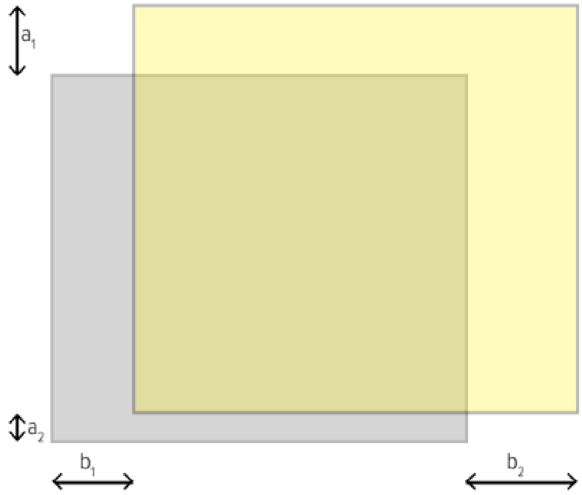

Figure 13: Collimator light field and beam alignments. The sum of differences between the light and the X-ray field in each direction should be less than 2% of the FDD (focal spot to detector distance). This can be calculated by obtaining a1, a2, b1 and b2 as follow:

(a_1= 0, a_2= -0.25, b_1= 0.25, b_2=0.75)

$|a_1| + |a_2| \leq 0.02 \times \text{FDD}$

$|b_1| + |b_2| \leq 0.02 \times \text{FDD}$

Collimator Light Field & Beam Alignment

Measure the distance between the light field borders, and the actual X-ray beam borders. Use the scale on the phantom. Make a note of the distances.

Table 11: Facility Information in the 2nd part of this work [10].

Name:	Rafa Medical Complex
City:	Riyadh

Survey Date:	15-Mar-2022
Due to Date:	14-Mar-2023

This quality control test has done according to the intentional standard reports (AAPM No.74) and National recommendations of King Abdullah City for Atomic & Renewable Energy.

Table 12: Machine Information in the 2nd part of this work.

Department/Room:	Radiology Dept. X-ray room	Model No.	E7884X
Manufacture:	Drgem	Serial No.	3H582

The Quality Control Test Result:

The purpose of repeated quality control testing is to validate precision and accuracy of the results of patient sample testing. Precision is the degree of agreement among repeated measurements of the same characteristic on the same sample, while accuracy is how close results are to what is expected from a test. The Calibration Accuracy Est. Confirm that, the X-Ray Machine Result is passed.

Table 13: Mechanical Checkup

Type of test	Pass/Fail
Movement of Tube	Passed
Movement of Table	Passed
Movement of tube aligned with Table	Passed
Movement of tube aligned with wall Bucky	Passed

QC Tests of Tube voltage, Exposure, and Exposure time:

The increase in x-ray tube voltage increases the amount of radiation coming out of the x-ray tube, as well as the average photon energy (i.e., increased penetration). Accordingly, the tube current exposure time product value (mAs) is reduced. The result shown in table 15 demonstrate that the coefficient of variation is around 0.1% and the limit is 10%. The mean value is 78.69 with Standard deviation of 0.02 kV and the maximum deviation from the mean value is 0.1% and the limit is 5%.

Exposure reproducibility:

Exposure Linearity: refers to a consistency in output radiation intensity at any select kVp settings when generator settings are changed from one milliamperage and time combination to another. The coefficient of variation was 0.3% (Limit: 10.0). The mean value is 0.5244 (Standard deviation: 0.001542mGy). The maximum deviation from the mean value is 0.3% (Limit 5.0%).

Table 15: QC Tests of Tube voltage, Exposure, and Exposure time. The mAs and kV were fixed of 10 mAs and 80 kV

#	Tube voltage (kV)	Exposure (mGy)	Exposure time (mS)
1	78.69	0.5260	50.17

2	78.71	0.5243	50.18
3	78.68	0.5229	50.20

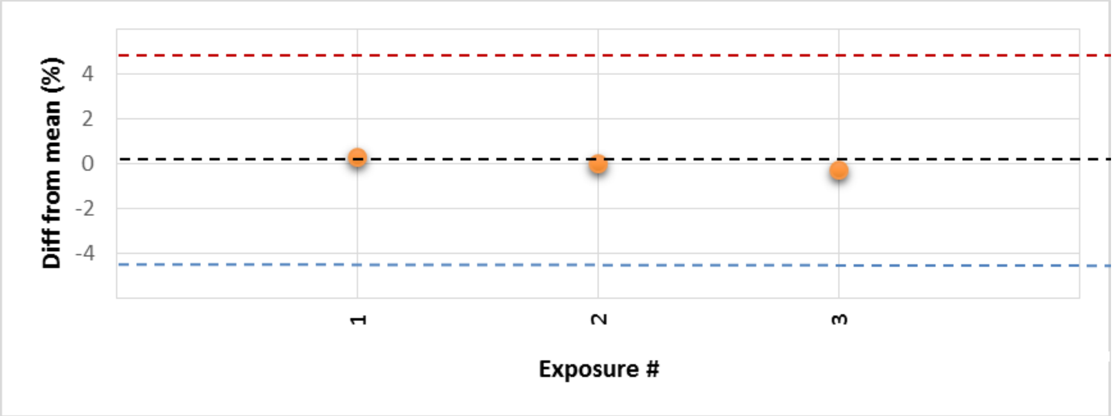

Figure 15: Exposure reproducibility for the 1st part of this work.

Exposure time reproducibility:

The ability of an exposure system to duplicate an exposure, time after time. It is expressed as a log exposure or as a percent exposure change. The smaller the change, the more reproducible the system. As demonstrated in table 16, the coefficient of variation was less than 0.1% and the limit is 10%. The mean value was 78.69 with standard deviation of 0.02kV. The maximum deviation from the mean value is also less than 0.1% and the limit is 5.0%.

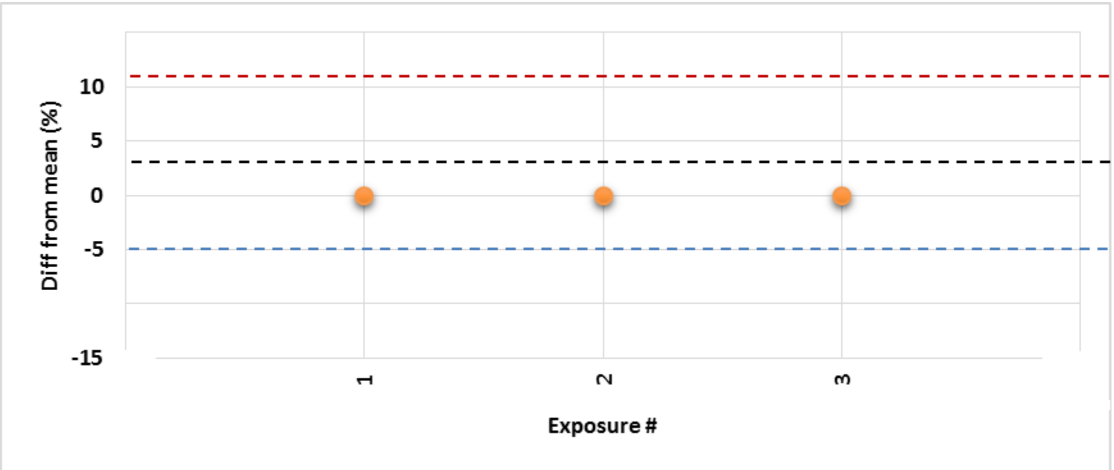

Figure 16: Exposure time reproducibility for the 2nd part of this work.

Tube Voltage Accuracy:

The increase in X-ray tube voltage increases the amount of radiation coming out of the X-ray tube, as well as the average photon energy (i.e., increased penetration). Accordingly, the tube current exposure time product value (mAs) is reduced.

Table 16: demonstrating the past results of Tube Voltage Accuracy. The maximum inaccuracy value was -2.1 % at 100 kV (Limit: -5.0 % to 5.0 %)

#	Set kV (kV)	Tube voltage (kV)	kVp diff%	Exposure (mGy)	Exposure time (mS)
1	50	49.10	-1.8	0.1862	49.71

2	60	59.33	-1.1	0.2240	38.14
3	70	69.17	-1.2	0.4061	49.70
4	80	78.73	-1.6	0.5244	50.19
5	90	88.42	-1.8	0.6635	50.18
6	100	97.93	-2.1	0.8097	50.20
7	110	108.04	1.8	0.9673	50.17

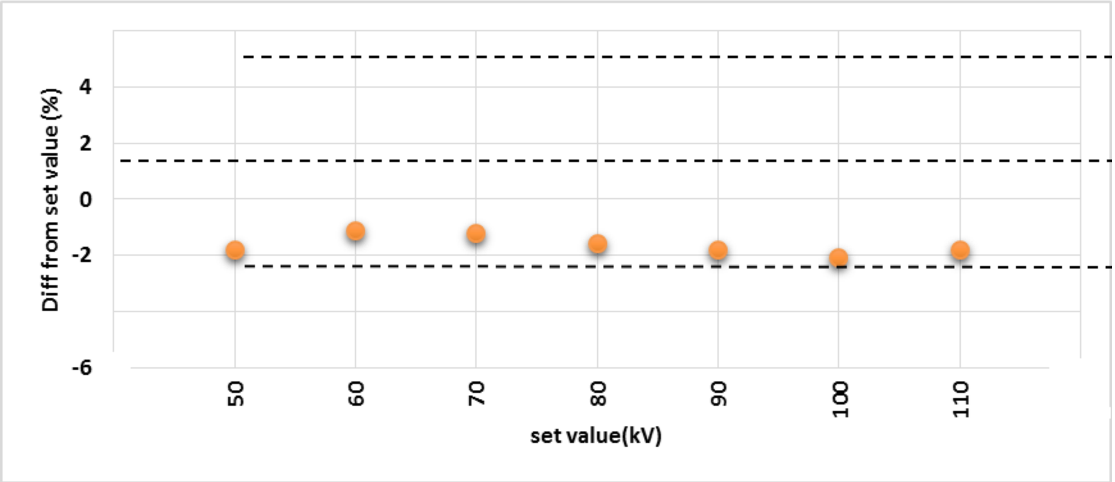

Figure 17: Tube Voltage Accuracy

Table 17: The mAs linearity and the results shown below demonstrate a Pass. Note that the kVp was sat to 80.

#	Set mAs (mAs)	Focal spot	Exposure (mGy)	Exposure/mAs (mGy/mAs)
1	10.00	Small	0.5215	0.05215
2	20.00	Small	1.037	0.05187
3	40.00	Large	2.074	0.05185
4	80.00	Large	4.143	0.05179

mAs linearity:

Quality control in diagnostic radiography begins with production of predictable exposures. As described above the mAs linearity measured to determine if the X-ray unit produces the same radiation output linearity for the same kVp and mAs regardless of the mA station used. Figure 19 demonstrate the radiation output linearity is the ability of a. radiographic aircraft to produce a constant radiation output from various. combinations of kV, mA, and X-ray exposure time. The HVL and the image quality test were measured in table 18 and table 19 respectively.

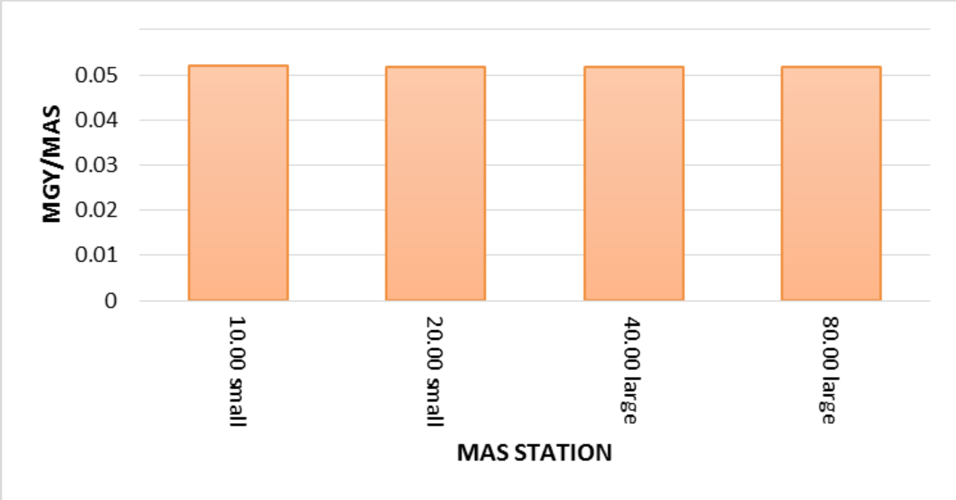

Figure 18: mAs linearity the 2nd part of this work. The result was pass and the maximum difference in mGy/mAs between adjacent stations: 0.3% (limit 10.0%). Linearity is a level of radiation output that is proportional to the use of various. exposures (kV and mA).

Half Value Layer:

Table 18: The Half Value Layer for the 2nd part of this work

c	Tube voltage(kV)	Exposure time (mS)	Exposure (mGy)	Exposure rate (mGy/s)	HVL (mmAI)	Total filter (mm AI)
1	78.84	50.20	1.040	10.36	3.19	3.4

Image Quality Test:

Table 19: The Image Quality Test for the 2nd part of this work.

Test	Test Results	Pass/Fail
Spatial Resolution	1.61 Ip/mm	Passed
Contrast Resolution	0.8%	Passed

CONCLUSION

Both X-ray machines assessed in this study indicated an acceptable performance, and does not required re-calibration for any parameters as timer accuracy/reproducibility and exposure reproducibility all passed all the QC tests. Based on the findings, kVp accuracy, kVp reproducibility, timer accuracy, timer reproducibility, exposure reproducibility, mA/timer linearity, and half-value layer were within the acceptable limits

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