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Survey of Quality Control of Dental X-ray Machines in Private Clinics in Riyadh

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ABSTRACT

Implementing a quality assurance (QA) program facilitate a radio diagnostic machine in acquiring sufficient radiological information of superior quality while minimizing the radiation dose administered to the subject. Integral to this program is Quality Control (QC), which ensures quality through various measurements and procedures. The main objective of this study is to assess the compliance of private dental clinics operating dental X-ray machines in Riyadh with the QC requirements. Fifteen private dental clinics in different areas in Riyadh selected and examined in the study. QC tests performed on all different X-ray machines from different manufacturers. The QC tests were kV accuracy and reproducibility, exposure time accuracy and reproducibility, and beam quality in terms of Half-Value Layer (HVL). Of the surveyed devices, two did not pass all the criteria for QC requirements. The dental X-ray machine that did not pass i.e. failed exclusively in kV accuracy but passed all the remaining QC tests. Particularly the exposure time reproducibility and Kilovoltage Accuracy. It is essential to establish a QC program in private dental clinics operating radiation-producing machines such as dental X-ray machines as it is important to ensure their compliance with the national standards for radiation safety.

Keywords: QC tests, Dental radiography, Kilovoltage accuracy, Radiation protection.

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INTRODUCTION

Dental X-rays are important diagnostic tools used by dentists to detect and assess a variety of dental conditions and problems, including cavities, gum disease, impacted teeth, tooth root health, bone density, bone loss, orthodontic issues, and oral cancers. Special emphasis placed on enhancing the quality assurance (QA) education in dental imaging, as radiation doses during dental examinations are generally modest. While digital imaging offers the potential to reduce doses while maintaining image quality, it also introduces the risk of dose escalation due to the ease and speed of acquiring multiple X-rays. Therefore, it is imperative to innovate new pedagogical methods to impart evidence-based learning to students and healthcare professionals. This approach supports their continuous learning throughout their careers to stay updated. The primary goal of this review is to contribute to the body of knowledge required for the development of QA education in digital dental imaging for healthcare personnel. Our project aims to deliver a systematic review of the fundamental competencies necessary for healthcare professionals, including radiographers engaged in quality assurance for digital dental radiological imaging. The QC tests for dental X-ray machine [1-5] carried out in this study; include Kilovoltage Accuracy, Kilovoltage Reproducibility, Exposure Time Accuracy and Beam Quality Half-value layer (HVL) [6].

MATERIALS AND METHOD

In this study, we assess the performance of several different machines model (see table 1) in Riyadh and conducted QC tests on them. Four tests namely Kilo-voltage Accuracy, Kilovoltage Reproducibility, Exposure Time Accuracy and Beam Quality HVL. All the QC tests carried out on Piranha MULTI X-ray meter base unit (see Figure 1). This is because such device is useful for qualified diagnostics and QA on Rad/Fluoroscopy, CT, Dental, and Mammography X-ray scans. It Measures kVp, Time, HVL, Total Filtration, Dose and Dose rate. Thus, such X-ray meter is a compact solution for fast and reliable testing covering all QA requirements [7-10].

Table 1: This a list of dental X-ray machines information

Symbol	Manufacture	Model No.	Serial No.
1	TAKARA BELMONT	DX-068	108021
2	Panpas	D-081	cd-21666
3	Sirona	D3507	36787
4	Carestream	CS 2100	AJYM386
5	Acteon group	X-mind	49082
6	Gendex corporation	46-404600G3	770-1199868DP
7	Fona XDC	CEI OX/70-G4	2910DC0167
8	Carestream	CS 2100	AJYM218
9	Carestream	CS 2100	AJYM003

10	De Gotzen	X-mind	322710
11	Carestream	CS 2100	EHYU334
12	TAKARA BELMONT	DX-068	M09096
13	Gendex corporation	112-0951G1	4200729
14	Sirona	D3507	499620
15	Castellini	CeI OCX/70-G	471186

Detector area: The rectangular marking indicates where the active detector area is located. The detector surface is located 10 mm below the surface; Minimum X-ray field is 3×21 mm.

The recommended field size is shown as red corners. (20×40 mm).

Power **switch (on edge):** Turns the Piranha on and off.

Indicators: for charging, status, and Bluetooth.

Figure1: The Piranha MULTI X-ray meter auto-detects probes, configures settings, and displays essential information on your PC. After use, data is stored for easy printing of a prepared report.

RESULTS AND DISCUSSION

The primary goal of Quality Assurance (QA) for an X-Ray machine is to guarantee minimal radiation exposure to patients while achieving optimal image quality in radiological procedures. It involves systematic actions aimed at instilling confidence in end-users that medical diagnostic X-ray equipment will operate satisfactorily, adhering to safety standards set by the Saudi Authority. QA for an X-Ray machine, following the Nuclear and Radiological Regulatory Authority (NRRA) program, primarily conducted during acceptance testing after the installation of the equipment at user institutions, ensuring compliance with specified operating licenses. Users are responsible for this aspect. Subsequent QC tests should occur at regular intervals, typically annually, and after equipment repairs or suspected malfunctions to ensure ongoing adherence to prescribed standards. This study is a prospective cross-sectional study that used convenience sampling in recruiting participants. More than 50 private dental clinics in different region of Riyadh approached from 2018 to 2020 to perform QC tests on their dental X-ray machines for the purpose of this study. Only 15 centers agreed to participate, and the authors performed QC tests on 15 dental X-ray machines during the period from 2018 to 2020. These tests encompass various examinations of the equipment [8]. The following subsections discusses and outlined the main results.

Tube Voltage Accuracy and Reproducibility

In X-ray imaging, optimal image quality and patient safety are contingent upon precise control of the tube voltage (kV). This parameter exerts a significant influence on both the quantity and quality of X-rays generated, directly affecting the final image's contrast and density. Any deviations from the intended kV setting can negatively affect image quality and potentially necessitate repeat exposures, leading to unintended increases in patient radiation dose. Peak kilovoltage (kVp) is the maximum voltage applied across the x- ray tube and governs the maximum energy of x-radiation produced. Accurately calibrated and consistent kVp are important in diagnostic imaging to control both optical density and contrast of the X-ray image. As well as radiation dose to the patient. It is worth pointing out that to assure that the actual kVp is accurate to within ± 5% of the indicated kVp and that the kVp is reproducible as indicated by a coefficient of variation less than or equal to 0.02. Therefore, ensuring accurate and reproducible kV output is paramount. The percentage error in kVp calculated using equation 1.

$\%kVp\ error = (V_0 - V□) / V□ * 10$ Eq. 1

Where V_0 is the selected kV setting and V□ is the measured kV value. Generally, adherence to international and national standards is crucial, mandating kV accuracy within ±5% of the selected value to guarantee proper image exposure and minimize unnecessary radiation exposure to patients. For machine number the tube voltage accuracy fail as the result exceeding the tolerance level. In Conclusion, from radiological point of view any radio-diagnostic equipment in radiology unit especially X-ray machine should have kVp limits within ±5%, which is the standard acceptable limits. While the kVp reproducibility (see table 2) allowed is within the limit of ±10%. An exemplar of tube voltage accuracy test shown in Figure 2.

Table 2: Kilo voltage reproducibility test. The maximum inaccuracy ≤ ±10%

Machine NO.	Result (fail/pass)	Machine NO.	Result (fail/pass)
1	-10.4 %(Fail)	9	4.6%(pass)
2	-9.3 %(Pass)	10	-3.0%(pass)
3	-0.5%(Pass)	11	1.6%(pass)
4	4.8%(Pass)	12	-8.7%(pass)
5	-2.6%(Pass)	13	1.3%(pass)
6	7.4%(pass)	14	-0.3%(pass)
7	-3.8%(pass)	15	-1.7%(pass)
8	2.1%(Pass)		

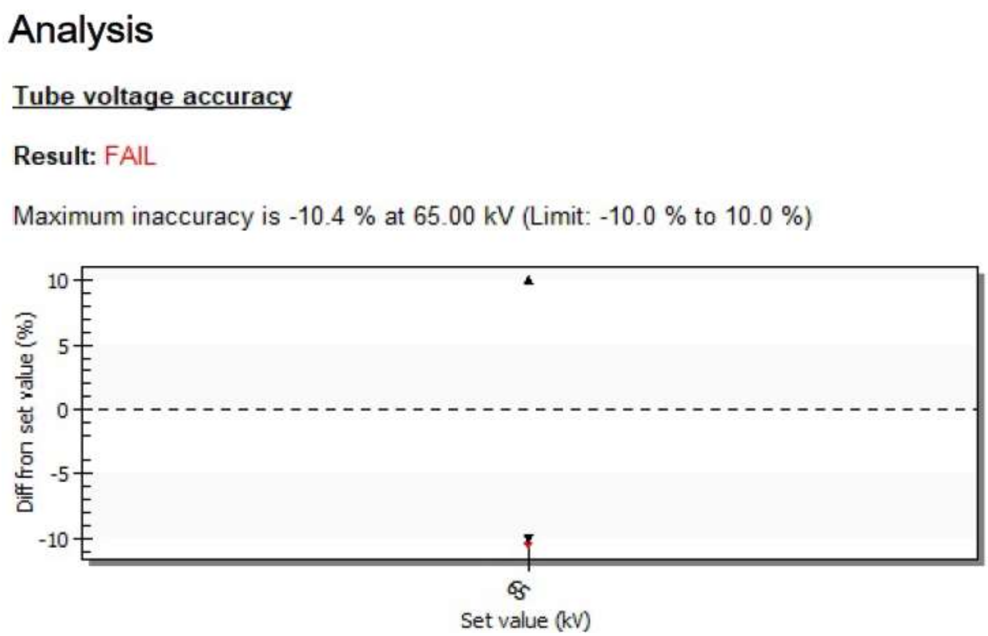

Figure 2: The tube voltage accuracy test for machine number 1 listed in table 2.

Table 3: Kilo voltage accuracy test.

Symbol NO.	Result (fail/pass)	Symbol NO.	Result (fail/pass)
1	0.2%(pass)	9	0.0%(pass)
2	0.2%(pass)	10	0.1%(pass)
3	0.1%(pass)	11	0.0%(pass)
4	0.1%(pass)	12	4.6%(pass)
5	0.2%(pass)	13	0.0%(pass)
6	0.5%(pass)	14	0.0%(pass)
7	0.1%(pass)	15	0.3%(pass)
8	0.2%(pass)		

Exposure time reproducibility

Ensuring the reproducibility of exposure time is crucial for QC in dental X-ray. Consistent exposure times guarantee optimal image quality for accurate diagnosis while minimizing radiation dose to patients. There are several methods to perform QC on exposure time reproducibility in dental X-ray units. The first one by using a dosimeter that measures radiation dose. This achieved by placing the dosimeter (see Figure 1) at a specific location on the dental X-ray unit. Then taking multiple exposures at the same selected exposure time setting, deviations in the measured dose will then detected. In other word, we test the reproducibility by using a dosimeter to measure the amount of radiation produced in a series of x-ray exposures made with the same settings. Then, we compare the readings from the dosimeter to see if they are the same each time. The second method by using a calibrated ion chamber that measures the ionization of air caused by X-rays. Like the dosimeter method, the ion chamber should be placed at a specific location and multiple exposures taken at the same selected exposure time setting. The consistency of the measured ionization values indicates reproducibility of exposure time. Finally, Dental X-ray units typically come with built-in features for monitoring exposure time. These features may include digital readouts or signal lights that confirm the selected exposure time delivered. The American Association of Physicists in Medicine (AAPM) recommends performing exposure time reproducibility tests annually on dental X-ray units. Daily or weekly tests performed, depending on the facility's specific protocols and risk assessments. By implementing a regular QC program for exposure time reproducibility, dental professionals can ensure they are delivering safe and effective diagnostic X-rays for their patients. Table 4 demonstrate the ability of an exposure system to duplicate an exposure, time after time for all machines. It expressed as a log exposure or as a percent exposure change. The smaller the change, the more reproducible the system. Piranha MULTI X-ray meter was calibrated for dental applications was used in the quality control testing. The piranha is a solid-state dosimeter that has an active width of 3 mm. In this study, the Piranha meter used to measure kVp, exposure time, and HVL.

Table 4: Exposure time reproducibility should be ≤ ±10%.

Machine NO.	Result (fail/pass)	Machine NO.	Result (fail/pass)
1	2.3% (pass)	9	0.1%(pass)
2	10.1%(fail)	10	0.0%(pass)
3	0.0%(pass)	11	0.0%(pass)
4	0.0%(pass)	12	4.6%(pass)
5	0.1%(pass)	13	0.1%(pass)
6	2.0%(pass)	14	0.1%(pass)
7	2.2%(pass)	15	3.0%(pass)
8	0.2%(pass)		

Half Value Layer (HVL)

HVL is the thickness of a material required to reduce the air kerma of an x-ray to half its original value. It applies to narrow beam geometry only, as with broad-beam geometry, a greater amount of scatter will reach the detector, overestimating the degree of attenuation. Such measurement usually performed using specialized equipment. A calibrated X-ray meter for dental X-ray (see Figure. 1) and filters often made of aluminum used. In this measurement process, the X-ray beam directed through the multi meter, and the initial intensity is measured. Filters of varying thicknesses then placed in the path of the beam, and the transmitted intensity measured for each filter thickness. The data analysis: By plotting the measured intensity versus filter thickness, the HVL can be determined graphically or mathematically. The HVL is the thickness of the filter material that reduces the beam intensity to half its original value. The result should be within the limits. This were demonstrated in table 5 and table 6 respectively.

Table 5: Half Value Layer results should be within the limits.

Symbol NO.	Result (fail/pass)	Symbol NO.	Result (fail/pass)
1	pass	9	pass
2	pass	10	pass
3	pass	11	pass
4	pass	12	pass
5	pass	13	pass
6	pass	14	pass
7	pass	15	pass
8	pass		

Table 6: Half Value Layer results of all dental machines investigated in this study. It represent the thickness of material necessary to lower an x-ray or gamma ray's air-kerma to half of its initial value intensity. In contrast to linear and mass attenuation coefficients, which are used to measure mono-energetic beams.

c	Tube voltage(kV)	Exposure time (ms)	Exposure (mGy)	Exposure rate(mGy/s)	HVL (mm Al)[1]	Total filter(mm Al)	Pulses
1	61.14	436.1	1.724	3.954	1.67	2.1	27
2	57.70	3254	5.179	3.331	1.78	2.6	94
3	71.98	199.8	1.538	7.699	2.01	2.2	1
4	64.50	199.3	1.080	5.421	2.06	2.8	1
5	80.30	100.4	1.518	15.12	2.97	2.8	1
6	74.69	579.7	2.482	4.283	2.26	2.6	27
7	69.31	326.7	2.704	8.278	2.42	3.3	1
8	63.01	199.2	1.058	5.311	2.12	3.1	1
9	64.62	199.3	1.239	6.220	2.15	3	1
10	70.61	452.2	1.304	2.884	2.08	2.4	28
11	62.32	628.3	2.968	4.724	1.96	2.7	1
12	63.03	585.1	3.194	5.458	1.75	2.2	36
13	67.33	495.8	2.652	5.349	2.15	2.8	1
14	72.76	498.8	5.967	11.96	2.04	2.2	1
15	71.61	351.8	2.304	6.548	2.01	2.2	22

CONCLUSION:

Dental X-rays are essential diagnostic tools for dentists, but they also expose patients to ionizing radiation. Therefore, it is important to implement QA measures to ensure that dental X-rays used safely and effectively. This study help develop better training for healthcare workers on how to make sure that digital dental X-rays are safe and effective. The goal is to make sure that healthcare workers have the skills they need to keep patients safe from radiation while still getting the images they need. This study gives an insight into the level of compliance of private dental clinics in Riyadh with the quality control requirements of dental X-ray equipment.

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