QUALITY CONTROL OF PANORAMIC AND INTRAORAL DENTAL UNITS IN ALBANIA

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Abstract

All medical radiological departments that use X-ray modalities, from the simplest intraoral dental unit to the most complicated interventional ones, would ensure high reliability in obtaining a high-quality image if they were subject to a periodic quality control program (QC). The purpose of this study was to assess whether the main exposure parameters for panoramic and intraoral units used by dental clinics in Albania are in good compliance with national standards. The evaluated QC parameters showed kilovoltage accuracy ranging from 0.4-6.9% for panoramic units and 0.2-3.9% for intraoral units. Kilovoltage reproducibility ranging from 0.0-3.0% for panoramic units and 0.1-3.3% for intraoral units. Exposure time accuracy ranging from 0.0-2.7% for panoramic units and 0.0-0.8% for intraoral units. Time precision ranging from 0.0-4.4% for panoramic units and 0.0-1.4% for intraoral units. Kilovoltage with change of mA ranging from 0.7-5.9% for panoramic units and 0.3% for intraoral unit. Output radiation reproducibility ranging from 0.1-4.0% for panoramic units and 0.0-0.03% for intraoral units. Output radiation with the change of mA ranging from 0.04–3.9% for panoramic units and 0.2% for intraoral unit. Total filtration exceeded 1.5 mmAl for kV lower than 70 as well as 2.5 mmAl for kV greater than 70. Radiation dose ranging between 30-80μGy/mAs. Based on the findings, this study demonstrated that all dental X-ray units routinely subjected to QC program in dental practices met the acceptable criteria of our national standards, ensuring adequate radiation protection for patients.

Key words: *dental radiography, panoramic equipment, intraoral, quality control tests, X- ray radiation.*

Përmbledhje

Të gjithë departamentet radiologjike mjekësore të cilët përdorin modalitete me rreze - X, nga njësia më e thjeshtë dentare intraorale deri tek ato më të komplikuara intervenuese do siguronin një besueshmëri të lartë në marrjen e një imazhi sa më cilësor nëse i nënshtrohen një programi periodik të kontrollit të cilësisë (KC). Qëllimi i këtij studimi ishte të vlerësonte nëse parametrat kryesorë të ekspozimit për njësitë panoramike dhe intraorale që përdoren nga klinikat dentare në Shqipëri janë në përputhje të mirë me standardet kombëtare. Parametrat e QC të vlerësuar treguan saktësi të kilovoltazhit që varionte nga 0.4-6.9% për njësitë panoramike dhe 0.2-3.9% për njësitë intraorale. Përsëritshmëria e kilovoltazhit varionte nga 0.0-3.0% për njësitë panoramike dhe 0.1-3.3% për njësitë intraorale. Gabimi në shkallën e kohë shënuesit varionte nga 0.0-2.7% për njësitë panoramike dhe 0.0-0.8% për njësitë intraorale. Saktësia në matjen e kohës varionte nga 0.0-4.4% për njësitë panoramike dhe 0.0-1.4% për njësitë intraorale. Kilovoltazhi me ndryshimin e mA-së varionte nga 0.7-5.9% për njësitë panoramike dhe 0.3% për njësinë intraorale. Përsëritshmëria e rrezatimit dalës varionte nga 0.1-4.0% për njësitë panoramike dhe 0.0-0.03% për njësitë intraorale. Rrezatimi dalës me ndryshimin e mA-së varionte nga 0.04-3.9% për njësitë panoramike dhe 0.2% për njësinë intraorale. Filtrimi total tejkaloi 1.5 mmAl për kV më të ulët se 70 si dhe 2.5 mmAl për kV më të lartë se 70. Doza e rrezatimit varionte midis 30-80 μGy/mAs. Bazuar në gjetjet, ky studim tregoi se të gjitha njësitë dentare me rreze X, të përfshira rregullisht në programin e kontrolleve të cilësisë në praktikat dentare plotësuan kriteret e pranueshme të standardeve tona kombëtare, duke siguruar mbrojtje të mjaftueshme nga rrezatimi për pacientët.

Fjalë kyçe: *radiografi dentare, pajisje panoramike, intraorale, testet e kontrollit të cilësisë, rrezatimi – X.*

Introduction

Dental radiographic imaging is generally used by dentists for the examination and treatment of various dental diseases such as malignant masses, bone loss, cavities, changes in bone density, etc. Dental radiography is broadly categorized into intraoral and extraoral techniques, each serving distinct diagnostic purposes. Intraoral techniques are used to obtain high resolution images of individual teeth and surrounding bone structures while extraoral

techniques are used to detect dental problems in the jaw and skull (Lommen et al, 2021), (Safety Reports Series. No. 108). Advances in imaging technology have led to the widespread use of multiple modalities, including intraoral radiography (i.e. bitewing, periapical and occlusal), panoramic radiography, cephalometric radiography and cone beam computed tomography which use different tools in the attempt to obtain the best image and treat efficiently any disease (Geibel et al, 2025). This study includes only intraoral and panoramic dental radiology modalities used in dental clinics across Albania. In intraoral examinations, X-rays pass through the oral structures and are captured by a film or digital receptor positioned between the patient's teeth. In contrast, panoramic examinations involve rotation of the X-ray tube and detector in a semicircular path around the patient's head, producing an image from one side to the other (Molander et al, 1995), (Safety Code 30, 2022). Although dental radiographic procedures generally involve low radiation doses, they constitute a significant portion of total medical X-ray procedures widely used. Their high frequency particularly among younger patients with increased radio-sensitivity raises concerns regarding cumulative radiation exposure (Ludlow et al, 2008), (Metsälä et al, 2014).

Poor image quality can result in repeated examinations, thereby increasing unnecessary radiation risks. Consequently, optimizing image quality and minimizing repeat imaging are essential to reduce unnecessary radiation risks to patients. Optimizing image quality through rigorous quality control (QC) programs is essential to minimize patient exposure and ensure accurate diagnoses (Benavides et al, 2024), (Ameli et al, 2025). The risk for the individual patient who undergoes only one dental radiographic examination is very low, but if the frequency of such examinations for the same patient increases or if the number of people undergoing such examinations increases, the risk of a population increases (Tsapaki, 2017), (Technical Report Series No. 457, 2007). Development and application of a proper QC program is essential for each country to ensure that these devices operate optimally all the time, providing accurate diagnostic information (Hatziioannou et al 2005), (Akpochafor et al, 2016), (IAEA, Human Health Series; no. 47, 2023).

Effective QC programs should begin immediately after equipment installation and continue systematically identifying technical issues over time and determining when corrective action is necessary including, if possible, taking the equipment out of service. Quality assurance measurements ensure that the equipment generates as many X-rays as necessary to keep radiation exposure

as low as possible not only for the patient's safety but also for the safety of personnel and the public (AAPM Report No. 74, 2002), (AAPM Task Group 175, 2016), (Ministry of Health-No. 404.2014). Being a developing country, the implementation of technical control for radiological medical devices in Albania has been established over the past decade and is regulated by the Ministry of Health in accordance with international standards (Ministry of Health-No. 404.2014), (IPEM Report 91, 2005). All radiological equipment used in Albania are required to undergo periodic technical inspection at least every three years.

This study aimed to evaluate whether panoramic and intraoral radiological units operated by dental clinics in Albania are in compliance with national radiation safety standards, demonstrating that rigorous QC procedures contribute to radiation protection and extend the operational lifespan of radiological equipment.

Material and methods

QC for dental radiological equipment is carried out based on Decision No. 404, dated 18.06.2014, "On the basic rules of radiological installations in medicine" for our country, paragraph Dental Radiography (Ministry of Health-No. 404.2014). The evaluation of the QC test measurements on seven panoramic dental units and six intraoral dental units presented in this study was performed by the QC laboratory of medical X-ray devices, which is part of the Department of Radiometry and Radiochemistry at the Institute of Applied Nuclear Physics (IANP) in Albania.

All measurements were performed with the AGMS - DM+ detector together with the ACCU-GOLD + Digitizer Module, manufactured by RADCAL, and the auxiliary device Multi-sensor Positioner (Model 8462C+) which aims at the precise orientation of the X-rays emerging from the source and falling on the detector using self-developing Gafchromic X-ray films (AAPM 175, 2016), (Safety Reports Series. No.108). In Figure 1 and 2, are presented, photos of the panoramic and intraoral dental units respectively during preparation for the start of the measurement process.

Figure 1. Panoramic dental graph

Figure 2. Intraoral dental graph

The solid-state detector is used for dental X-ray, radiography/fluoroscopy, and mammographic range measurements. It can measure kVp, dose, dose rate, time, HVL, total filtration and waveforms, automatically recording the measurements for each exposure by Accu-Gold Software. Technical specifications of the solid-state detector used for QC tests measurements are listed below: the kVp measurement range is 21-160kV with uncertainty of ± 2%, the dose measurement range is 40nGy-100Gy with uncertainty of ±5%, the HVL measurement range is 1.3-13.5mm Al with uncertainty of ±5% and the dose rate measurement range is 40nGy/s-200mGy/s with uncertainty of ±5%. To ensure the accuracy of QC tests measurements, all the instruments used for QC testing performance must be calibrated at regular intervals against accepted standards depending on their use. The instruments used by IANP ensures the measurement traceability by the Hellenic Atomic Energy Commission (EEAE).

The operating tube voltage for all the dental equipment included in this study was found to be larger than 50 kV. During all measurement procedures, exposure time ranged from 9s-14s and milliamperage ranged from 6-12 mA for panoramic units. For intraoral unit's exposure time ranged from 0.13s-0.32s and milliamperage ranged from 3-8 mA.

For kilovoltage accuracy test, kV was measured at three different nominal kV settings 60-80 according to the clinical protocol used by each unit. The readings were recorded, and the percentage difference from the nominal kV settings was calculated. For reproducibility assessment, three measurements were performed and the percentage difference from the mean value was calculated. The tube output measurement was performed at ranges 60-70 kV setting and calculated at one meter from the focus. The measured kV, tube output radiation,

exposure time and total filtration were recorded automatically for each exposure. After recording the measurements results all calculations were performed using Microsoft Excel Software.

Analysis and discussion

Dental clinics that were selected to participate in this study are located in different cities of Albania. The panoramic and intraoral dental radiological equipment are marked with capital letters A, B, C, D, E, F, G and H, I, J, K, L, M respectively. They belong to various manufacturers: Hyperion, Carestream Cefla and Owandy etc.

The measurement results for the kVp accuracy and filtration tests recorded for panoramic units are reported in Table 1 whereas, measurement results for the kVp accuracy and filtration tests recorded for intraoral units are reported in table 2.

The maximum deviations for kVp accuracy tests reported in table 1 and table 2 are expressed in percentage.

Table 1. kVp accuracy measurement results and filtration for panoramic units

Unit	kV set	kV measured	Deviation (%)	Passing criteria <10%	Filtration Measured (mmAl)	Passing criteria (mmAl)	Pass/Fail
A	60	60.6	1.0	Pass	1.8	> 1.5	Pass
	70	73.1	4.4	Pass	2.7	> 2.5	Pass
	80	80.3	0.4	Pass	3.2	> 2.5	Pass
B	60	62.1	3.5	Pass	2.5	> 1.5	Pass
	75	76.9	2.5	Pass	3.2	> 2.5	Pass
	80	82.5	3.1	Pass	3.4	> 2.5	Pass
C	60	64.1	6.8	Pass	2.6	> 1.5	Pass
	70	73.3	4.7	Pass	2.8	> 2.5	Pass

	80	85.5	6.9	Pass	2.8	> 2.5	Pass
D	60	62.7	4.5	Pass	3.8	> 1.5	Pass
	73	72.5	0.7	Pass	3.8	> 2.5	Pass
	80	80.7	0.9	Pass	3.8	> 2.5	Pass
E	65	61.5	5.4	Pass	2.9	> 1.5	Pass
	72	67.5	6.3	Pass	2.9	> 2.5	Pass
	80	75.3	5.9	Pass	2.9	> 2.5	Pass
F	60	61.1	1.8	Pass	2.9	> 1.5	Pass
	70	70.4	0.6	Pass	3.1	> 2.5	Pass
	80	79.3	0.9	Pass	4.7	> 2.5	Pass
G	60	59.1	1.5	Pass	5.7	> 1.5	Pass
	70	70.3	0.4	Pass	5.3	> 2.5	Pass
	80	83.1	3.9	Pass	5.1	> 2.5	Pass

From the reported results shown in table 1, it was concluded that, for kVp accuracy test, the deviation ranged from 0.4% for panoramic unit A and G to 6.9% for panoramic unit C.

Filtration values recorded for kV lower than 70 ranged from 1.8 mmAl for panoramic unit A to 5.7 mmAl for panoramic unit G, meanwhile filtration values recorded for kV larger than 70 ranged from 2.7 mmAl for panoramic unit A to 5.3mmAl for panoramic unit G.

Table 2. kVp accuracy measurement results and filtration for intraoral units

Unit	kV set	kV measured	Deviation (%)	Passing criteria <10%	Filtration Measured (mmAl)	Passing criteria (mmAl)	Pass /Fail
H	60	59.9	0.2	Pass	1.9	> 1.5	Pass
	65	64.7	0.5	Pass	2.1	> 1.5	Pass
	70	69.3	1.0	Pass	2.3	>1.5	Pass
I	70	69.2	1.1	Pass	3.1	> 1.5	Pass
J	60	59.1	1.5	Pass	2.1	> 1.5	Pass
K	70	67.3	3.9	Pass	2.4	> 1.5	Pass
L	60	61.2	2.0	Pass	2.2	> 1.5	Pass
M	70	71.2	1.7	Pass	2.6	> 1.5	Pass

From the reported results shown in table 2, it was concluded that all intraoral units included in the study operate only in one tube potential, which is 60kV or 70 kV, except the first one (H), which operates in three different tube potentials: 60, 65 and 70kV. For kVp accuracy test, the minimum deviation was 0.2% and belongs to intraoral unit H, while the maximum deviation was 3.9% and belongs to intraoral unit K. Filtration results ranged from 1.9mmAl for intraoral unit H to 3.1mmAl for intraoral unit I.

Therefore, the measurements of kVp accuracy and total filtration values show very good agreement with the acceptance criteria specified in our national radiation protection regulation for all the evaluated units. The measurement results for six QC parameter tests for panoramic units are presented in table 3, meanwhile for intraoral units these results are reported in table 4. During measurements performance for these QC tests, it was noted that not all dental units had the possibility to change the mA values. Consequently, the accuracy of kVp with the change of mA test and output radiation with the change of mA test for non-applicable cases is marked with the symbol (NA).

Table 3. Measurement results of six QC parameters tests for panoramic units

Parameter test	Passing criteria (%)	Maximum deviation (%) Panoramic Units							Pass /Fail
		A	B	C	D	E	F	G	Pass
kVp reproducibility	<5	1.0	3.0	0.1	0.1	0.0	0.7	0.0	Pass
Exposure time accuracy	<20	0.0	2.7	0.4	0.2	0.0	0.1	0.4	Pass
Time precision	<10	0.4	2.7	4.4	0.0	0.0	0.0	0.0	Pass
kVp accuracy with change of mA	<10	1.6	NA	NA	0.7	5.9	1.6	3.9	Pass
Tube output reproducibility	<20	1.5	2.0	1.5	4.0	0.8	0.1	1.5	Pass
Tube output with change of mA	<15	0.04	NA	NA	2.1	0.7	1.4	3.9	Pass

Table 3 shows that for kVp reproducibility, the minimum deviation was 0.0% for panoramic unit E and G, while the maximum deviation was 3.0% for panoramic unit B.

For the exposure time accuracy test, the minimum deviation was 0.0% for panoramic unit A and E, while the maximum deviation was 2.7% for panoramic unit B. For the time precision test, the minimum deviation was 0.0% for panoramic unit D, E, F and G, while the maximum deviation was 4.4% for panoramic unit C. For kVp accuracy with change of mA test, the minimum deviation was 0.7% for panoramic unit D while, maximum deviation is 5.9% for panoramic unit E. For tube output reproducibility test, the minimum deviation was 0.1% for panoramic unit F, while the maximum deviation was 4.0% for panoramic unit D.

For tube output with change of mA test, the minimum deviation was 0.04% for panoramic unit A, while the maximum deviation was 3.9% for panoramic unit G. Based on these findings, we concluded that all the tests are within the specified limits in our national regulation for all the panoramic units investigated in this study, reporting an optimal performance for all the investigated X-ray dental units.

Table 4. Measurement results of six QC parameters tests for intraoral units

QC parameter test	Passing criteria (%)	Maximum deviation (%) Intraoral Units					Pass/ Fail
		H	I	J	K	L	Pass
kVp reproducibility	<5	0.2	0.1	1.5	3.3	2.3	Pass
Exposure time accuracy	<20	0.0	0.1	0.0	0.5	0.8	Pass
Time precision	<10	0.0	0.0	0.0	1.4	0.7	Pass
kVp accuracy with change of mA	<10	NA	0.3	NA	NA	NA	Pass
Tube output reproducibility	<20	0.03	0.0	0.0	0.0	0.0	Pass
Tube output with change of mA	<15	NA	0.2	NA	NA	NA	Pass

From the results reported in table 4, it was concluded that for the kVp reproducibility test, the minimum deviation was 0.1 % for unit I, whereas the maximum deviation was 3.3% recorded for unit K. Regarding the exposure time accuracy test, the minimum deviation is 0.0% for unit H and J, and maximum deviation was 0.8% for unit L. For the exposure time precision test, the minimum deviation was 0.0% for intraoral unit H, I and J, while the maximum deviation was 1.4% for intraoral unit K. The kVp accuracy with change of mA test, is applicable for only the I unit with 0.3% deviation. For tube output reproducibility, the minimum deviation was 0.0% for intraoral unit I, J, K and L, while the maximum deviation was 0.03% for intraoral unit H. For tube output with change of mA test, it is applicable for only the I unit with 0.2% deviation.

Based on these findings, all measured parameters were within the limits specified by our national regulation for all the intraoral units investigated in this study, demonstrating optimal performance. In table 5, are reported the tube output measurement results at one meter from the focus for panoramic and intraoral units.

Table 5. Tube output measurement results for panoramic and intraoral units

QC Test	Passing criteria	Panoramic units							Pass/ Fail
		A	B	C	D	E	F	G	
Tube output	30-80 µGy/mAs	31.4	40.5	40.1	34.1	32.1	33.9	37.5	Pass
		Intraoral units							
Tube output	30-80 µGy/mAs	H	I	J	K	L	M		Pass
		31.2	40.2	32.8	31.2	31.5	31.7		

Table 5 shows that tube output values ranged from 31.4µGy/mAs for panoramic unit A to the maximum value 40.5µGy/mAs for panoramic unit B. Meanwhile, for intraoral units, tube output values ranged from 31.2 µGy/mAs for H and K units to the maximum value 40.2µGy/mAs for the I unit, indicating that all measured radiation tube output values fall within the acceptable range of 30-80µGy/mAs.

These findings demonstrate full compliance with the acceptance criteria specified by the Albanian regulatory framework. However, considering recent developments in dental radiological equipment technology, including the increasing use of mobile dental radiology, and based on comparisons with international studies, this work highlights a lack of image quality assessment for dental radiological units in Albania. Consequently, it is strongly recommended that national regulatory authorities incorporate mandatory image quality assessment into the QC requirements for dental radiological units used in Albania. (J. Malone et al, 2013), (Pittayapat et al, 2010), (Udupa et al, 2013), (Radiation Protection No. 162, 2013).

Conclusions

A quality control evaluation for intraoral and panoramic radiographic units was conducted aiming to verify compliance with our national radiation protection requirements. Measurements of nine parameters including kilovoltage (kVp) accuracy and reproducibility, kVp variation with change of mA, accuracy and precision of the exposure time, total filtration, tube output and reproducibility,

as well as tube output variation with the change of mA were evaluated. Measurements were carried out using a RadCal solid - state detector by the quality control laboratory of diagnostic radiological devices at the Institute of Applied Nuclear Physic. Based on the analysis of results, it was concluded that all QC parameter tests were acceptable in 100% of equipment being within the acceptance criteria set out in our national radiation protection regulation.

Based on the latest development of new technologies and other studies, this paper highlights the need for the National Regulatory Authority to include the image quality assessment in quality control tests requirements for dental X-ray imaging modalities to make a quality control program more complete. Proving that the implementation of the quality control program in dental radiographic devices is in full compliance with the latest legal requirements ensures the acquisition of high-quality images and the protection of patients from radiation exposure. Failure to perform quality control regularly can have serious implications for entities, including patient dissatisfaction, increased radiation safety concerns, inefficient image production processes, and non-compliance with radiation protection regulations.

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