Dose implications of X-ray beam alignment in some radiological facilities in Abuja, Nigeria

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Abstract: In this study, the percentage misalignment of X-ray beam and patient radiation dose of chest X-ray examination in radiographic X-ray equipment in some selected centres in Abuja were investigated. Beam alignment test was carried out in order to determine the working status and possible contribution to population radiation dose. The tools used were the beam alignment and collimator test tool Model 161A and Model 161B respectively. A total of four functional X-ray machines in four radio-diagnostic centres labelled in code for ethical reasons were recruited for the study. Results indicate that the beam alignment test conducted, 50% shows positive misalignment beyond the normal limit of 2% while 50% shows beam alignment within the normal limit. The percentage misalignment value ranged from 1.6% to 3.4% and 1.4% to 2.6% across and along the cassette respectively. Entrance Skin Dose (ESD) was calculated for patients undergoing chest X-ray examination in two selected diagnostic centres and was found 273.1 µGy and 491.6 µGy which appears to be lower and higher respectively to the recommended limit by international regulatory bodies. Increase in patients' radiation dose is expected due to the beam misalignment in most of the diagnostic centre studied. It is therefore recommended that regulatory agencies should monitor compliance with quality assurance tests in all radio-diagnostic centres in Abuja.

Keyword: X-ray Beam Allignment, Entrance Skin Dose, Thermoluminescent dosimeter.

1. INTRODUCTION

Medical exposure accounts for 98% of contributions from all artificial sources and contributes 20% to the total population dose worldwide. A typical conventional X-ray machine has different component parts that helps in beam restrictions and collimation. These parts control the field size of X-ray beam passing through the patient onto the film thereby reducing the radiation dose to the patient and improving the radiographic image quality (Egbe et al., 2003). The purpose of quality assurance test is to improve the health condition of individuals in diagnostic centres. X-ray plays an important role in modern technology, especially for medical imaging purpose (Ian, 2004).

Numerous studies in diagnostic radiography has shown that it is far the greatest source of ionizing radiation to man since up to 60% of patients pass through radio diagnostics

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especially in developed countries UNSCEAR, 2000). A lot of concern has been shown by the manufacturers of X-ray equipment, medical physicists and radiographers with the purpose of reducing radiation dose to the patients. This concern is reflected in every decision made especially in the designing of the equipment and techniques adopted for a radiological procedure. Proper radiation protection of the patient is achieved through medical and technical decision. Medical decisions lies with the patient and are based on the professional judgement of the physicians and other medical practitioners in consultation with the patient while the technical decisions include a number of factors that affect the amount of radiation a patient receives during a diagnostic X-ray examination (Egbe et al., 2003; Obot, 2008).

X-ray beam alignment is very important in the radiology facilities due to its vital role in avoiding excess radiation dose to the patients and also in the quality of the images that is gotten after the X-ray examination. In other to achieve this, the radiation medical practitioner or personnel must know the effects of misalignment the X-ray beam would have on the patients and radiographs (IAEA, 2007). The knowledge of these effects will help us to choose the right intensity for a given part of the body to be examined in other to obtain an acceptable radiograph or image. Most X-ray machines used in the country have been put into use for a long time since installation without any quality control test carried out on them. This includes some conventional X-ray machines used in some diagnostic centres in Abuja. Most of these machines never had any acceptance test conducted during their installation. Where such tests were conducted at all, no records of these results is retained in the facilities. It has been reported and as it is common in daily radiographic practice, that radiographers and other users of the final product of X-ray images often encounter radiographs which are off centred even when proper radiographic techniques are applied. The presence of this condition, which may be due to misalignment of the light field and the X-ray field, can be proved by means of quality control tests.

The system of radiation protection proposed by the International Commission on Radiological Protection (ICRP) has long been incorporated into UK legislation. Recommendation of the ICRP published 1991 were the basis of the European directives that forms the basis of current UK legislation. In Nigeria, the Nigerian Radiation Safety in Diagnostic and International Radiology Regulation published in 2006 gives a set of regulation which provide among others things, for the protection of patients, workers and the public from harmful effects of exposure to ionizing radiation. The regulation is a derivative of the international Basic Safety Standard (BSS) for protection against ionizing radiation sources (Valentin, 2007). The most important consideration in protecting the patient is to ensure that images produced are of sufficient quality for accurate diagnosis without the need of any repeat. The means of achieving these are in the design and maintenance of equipment, training and experience of staff, robust operating procedure and clinical protocol. Beam limitation is one of the practical methods stressed in today's practice used to reduce patient dose (Penelope & Williams, 2006).

According to WHO (1982), a quality assurance program which include quality control tests helps to ensure that high quality diagnostic image are consistently produced while minimizing radiation exposures. The program will enable the facility to recognize when parameters are out of limit which could result in poor quality images and can increase radiation exposure to the patient. This study aimed at assessing the X-ray beam alignment of X-ray machines and its dose implication on patients in radiology centres in Abuja.

2. Materials and Methods

This study investigate the percentage misalignment of X-ray beam and patient radiation dose of chest X-ray examination in radiographic X-ray equipment in four selected centres in Abuja. A RMI Beam alignment test tool (Model: 161A) and a Gammex Collimator test tool (Model: 161B) were used to measure the degree of X-ray beam misalignment. The various misalignments parameters (AC1, AC2, AL1 and AL2 in cm) were measured and recorded across and along the cassettes for each X- ray machine examined.

A random sampling technique was adopted to select forty patients dose patients' records that underwent chest X-ray examinations at two of the diagnostic centres. The forty records include twenty patients' records from one of the diagnostic centre whose X-ray machine was aligned properly and another twenty patients records from a different diagnostic centre whose X-ray machine was aligned properly.

The entrance surface dose (ESD) for patients was assessed by indirect method, using patient data that underwent chest X- ray examination. The focus-to-skin distance (FSD) and radiographic exposure factors (kVp and mAs) for each patient were collected and analysed. A self- designed Excel sheet was used to analyse and record the data. badge Thermo luminescence Dosimeter (TLD) was used to measure the X-ray tube output.

i. Percentage (%) Beam Misalignment: The expression for determining the percentage misalignment is given as stated by Egbe *et al.* (2003) and Lloyd (2001). To determine the percentage (%) misalignment of light field and X-ray field along and across the cassette, the total misalignment were divided by the focus to film distance (100 cm) and multiplied by 100 as follows:

$$Percentage\ (\%)\ misalignment\ accross\ the\ cassette\ = \frac{TOT\ AC}{FFD}\ x\ 100\% \tag{1}$$

and

$$Percentage\ (\%)\ misalignment\ along\ the\ cassette\ = \frac{TOT\ AL}{FFD}\ x\ 100\% \tag{2}$$

ii. Patient Radiation Dose Assessment: The Entrance Surface Dose was calculated using the exposure parameters: kilovolt peak (kVp), mili-ampere second (mAs), focus to skin distance (FSD) and back scatter factor (BSF) that were recorded during the procedure (Table 2). The calculation of ESD was done using the formula:

$$ESD = BSF\ x\ Tube\ Output\ x\ \left(\frac{kVp}{FSD}\right)^2\ x\ mAs \tag{3}$$

Where kVp is the peak tube voltage applied, FSD is focus-to-skin distance, mAs is the exposure current and the exposure time and BSF is the back scatter factor.

3. Results and Discussion

The result for the percentage (%) misalignment values for AC and AL in diagnostic centres under study are presented in Table 1 and Figure 1, while the result for the X-ray exposure factors, dose of patients and the calculated ESDs of patients undergoing chest X-ray examination at diagnostic centre XDC_3 and XDC_4 are presented in Tables 2 and 3.

Table 1: Percentage (%) misalignment values for AC and AL in diagnostic centres under study.

S/N	X-ray Centre	Field Size (cm)	Total AC (cm)	Total AL (cm)	AC (%)	AL (%)
1.	XDC_1	18 X 24	3.2	1.8	3.2	1.8
2.	XDC_2	18 X 24	1.6	1.4	1.6	1.4
3.	XDC_3	18 X 24	1.8	2.0	1.8	2.0
4.	XDC_4	18 X 24	3.4	2.6	3.4	2.6

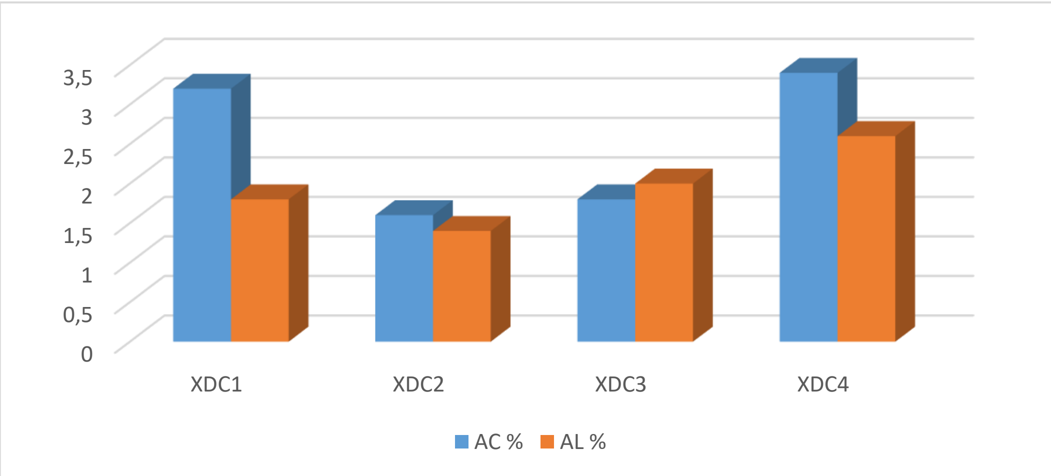

Fig. 1: Percentage Misalignment for AC and AL for the diagnostic centres under study

Table 2: X-ray exposure factors and dose of patients undergoing chest X-ray examination at diagnostic centre XDC_3

S/N	Tube Output	kVp	mAs	FSD (cm)	ESD (mGy)
1.	0.03017	70.00	20.00	126	0.2514
2.	0.03017	85.50	19.00	128	0.3413
3.	0.03017	53.00	21.00	123	0.1581
4.	0.03017	78.00	20.00	124	0.3223
5.	0.03017	66.00	21.50	119	0.2694
6.	0.03017	90.00	22.50	128	0.4531
7.	0.03017	60.00	20.00	120	0.2036
8.	0.03017	88.00	19.00	127	0.3716
9.	0.03017	62.00	20.00	125	0.2004
10.	0.03017	71.00	20.00	124	0.2671
11.	0.03017	73.00	16.00	123	0.2295
12.	0.03017	65.00	18.50	126	0.2005
13.	0.03017	60.00	18.00	128	0.1611
14.	0.03017	70.00	21.00	127	0.2598
15.	0.03017	82.00	19.00	125	0.3330

16.	0.03017	75.00	16.05	120	0.2554
17.	0.03017	67.00	20.00	126	0.2302
18.	0.03017	80.00	18.00	125	0.3003
19.	0.03017	75.00	19.00	128	0.2657
20.	0.03017	85.00	19.00	120	0.3883
Mean	**0.03017**	**72.75**	**21.28**	**124.6**	**0.2700**

Table 3: X-ray exposure factors and dose of patients undergoing chest X-ray examination at diagnostic centre XDC_4

S/N	Tube Output	kVp	mAs	FSD (cm)	ESD (mGy)
1.	0.04752	80.00	23.00	130	0.5588
2.	0.04752	70.00	25.00	127	0.4872
3.	0.04752	70.00	20.00	128	0.3837
4.	0.04752	80.00	25.00	132	0.5891
5.	0.04752	85.00	25.00	130	0.6856
6.	0.04752	70.00	22.00	126	0.4356
7.	0.04752	80.00	25.00	130	0.6074
8.	0.04752	75.00	22.00	126	0.5001
9.	0.04752	80.00	25.00	128	0.6265
10.	0.04752	70.00	21.00	124	0.4293
11.	0.04752	90.00	22.00	132	0.6561
12.	0.04752	65.00	19.00	125	0.3296
13.	0.04752	60.00	20.00	125	0.2956
14.	0.04752	75.00	22.00	128	0.4845
15.	0.04752	80.00	20.00	130	0.4859
16.	0.04752	70.00	25.00	125	0.5030
17.	0.04752	65.00	18.00	122	0.3278
18.	0.04752	70.00	22.00	126	0.4356
19.	0.04752	80.00	25.00	128	0.6265
20.	0.04752	70.00	20.00	128	0.3837
Mean	**0.04752**	**74.25**	**22.30**	**127.5**	**0.4916**

It can be observed from Table 1 that the highest percentage (%) misalignment value recorded across (AC) the cassette was 3.4% at diagnostic centre XDC_4 while the lowest was 1.6% at diagnostic centre XDC_2. For misalignment value along (AL) the cassette, the highest percentage (%) misalignment value recorded was 2.6% at diagnostic centre XDC_4 while the lowest was 1.4% at diagnostic centre XDC_2. Figure 1 showed the bar chart of percentage misalignment for AC and AL for the diagnostic centres under study.

Table 2 and 3 showed that the mean values obtained for ESD for chest X-ray examinations to be 0.27mGy and 0.49mGy for diagnostic centre XDC_3 and XDC_4 respectively. The results obtained are then compared with the mean values obtained from other related work. Table 4 showed mean ESD comparison of the present study with international diagnostic reference values UNSCEAR (2000), IAEA (2007) and NRPB (2000) given as 0.05mGy, 0.20mGy and 0.3mGy respectively for chest X-ray examination. The results obtained showed that ESD, for patient undergoing chest X-ray examination in diagnostic centre XDC_3, lies within the required diagnostic reference value. Whereas the ESD values for patient undergoing chest X-ray examination in diagnostic centre XDC_4 is higher than the diagnostic reference values given by UNSCEAR (2000), IAEA (2007) and NRPB (2000).

In order to find out the difference of ESDs of the standard and calculated values, we used the descriptive statistics for the variable, paired samples correlations, and paired t-test as shown in Tables 5, 6 and 7 respectively. The dependent variable is the ESD4 which was calculated alongside the standard values; standard and calculated. The independent variables are the Diagnostic Centres.

Table 4: Comparison of present study with established international DRLs

Diagnostic Centre	ESD Values (mGy)			DRL Values		
	Min	Max	Mean	NRPB (2000)	UNSCEAR (2000)	IAEA (2007)
XDC3	0.16	0.45	0.27	0.30	0.05	0.20
XDC4	0.30	0.69	0.49			

Table 5: Descriptive Statistics for each Variables

		Mean	N	Std. Deviation	Std. Error
Pair 1	ESD4	0.4945	20	0.11754	0.02628
	NRPB	0.3000	20	0.00000	0.00000
Pair 2	ESD4	0.4945	20	0.11754	0.02628
	UNSCEAR	0.0500	20	0.00000	0.00000
Pair 3	ESD4	0.4945	20	0.11754	0.02628
	IAEA	0.2000	20	0.00000	0.00000

Table 6: Paired Samples Correlations

		N	Correlation	Significance
Pair 1	ESD4 & NRPB	20	0.000	0.000
Pair 2	ESD4 & UNSCEAR	20	0.000	0.000
Pair 3	ESD4 & IAEA	20	0.000	0.000

Table 7: Paired Samples Test of ESD Values

	Paired Difference						t-Value	Diff.	Sig. (2-tailed)
	Mean	N	Std. Div.	Std. Err. Mean	95% Conf. Inter. Diff.				
					Lower	Upper			
Pair 1 ESD4-NRPB	0.1945	20	0.11754	0.02628	0.13949	0.24951	7.400	19	0.000
Pair 2 ESD4-UNSCEAR	0.4445	20	0.11754	0.02628	0.38949	0.49951	16.912	19	0.000
Pair 3 ESD4-IAEA	0.2945	20	0.11754	0.02628	0.23949	0.34951	11.205	19	0.000

Table 5 shows the mean of the standard ESD and calculated ESD4, the number of patients, the standard deviation and the standard error. The important results are the mean and the standard deviation. The standard deviation values are not the same in all cases which shows that there is variation in the sample. The mean of the calculated ESD4 values are greater than the mean of standard ESD values in all cases. Implying that there is a beam misalignment of the machine at the diagnostic centre XDC4. This difference in mean of the standard ESD and calculated ESD4 whether it is significant or not will be determine by the paired sample t-test.

Table 6 is the results of the paired samples correlations. The values are correlated for correlation value > 0.5, but in this study there was no correlation in the value of the standard ESD and calculated ESD4 with correlation r = 0.000 and p-value = 0.000 in all cases.

Table 7 is the result of the paired t-test which shows the mean difference between the mean value of the standard ESD and calculated ESD4, standard deviation, standard error mean, 95% confidence interval of the difference, t-value, degree of freedom, and the 2-tailed significant level (p-value). The negative or positive sign of the mean does not matter. It depends on the arrangement of the variable for mathematics. The significant level is determined by the p-value, usually if $p < 0.05$ implies that it is significant at 95%, but in this study, the p-value shown here is $p < 0.0001$ which implies that it is 99.9% significant, showing that the difference in the standard ESD and calculated ESD4 is highly significant. By implication, it means that the X-ray beam output of the machine at the diagnostic centre XDC4 was not well aligned.

Another result we can get from Table 7 is the 95% confidence interval of the difference which shows what kind of difference we are expected to see in the sample. If one sign is positive and the other sign is negative of the upper and lower confidence interval, it means we don't know if the mean of the standard ESD are higher or lower than the mean calculated ESD4. But if the upper and lower confidence interval are both either positive or negative then it means that there is a difference between the mean of the standard ESD and calculated ESD4. Considering NRPB (2000) recommended ESD value for example, it shows from the lower value that the NRPB standard ESD is at least 0.3672 lower than the calculated ESD4. And from the upper value that the calculated ESD4 is at most 0.4213 greater than the NRPB standard ESD. This means that the true difference between the means lays between the two values: between 0.3672 and 0.4213 and we are 95% certain. Considering UNSCEAR (2000) recommended ESD value for example, it shows from the lower value that the UNSCEAR (2000) standard ESD is at least 0.1672 lower than the calculated ESD4. And from the upper value that calculated ESD4 is at most 0.2213 greater than the UNSCEAR standard ESD. This means that the true difference between the means lays between the two values: between 0.1672 and 0.2213 and we are 95% certain. Considering IAEA (2007) recommended ESD value for example, it shows from the lower value that the IAEA standard ESD is at least 0.3922 lower than the calculated ESD4. And from the upper value that the calculated ESD4 is at most 0.4463 greater than the IAEA standard ESD. This means that the true difference between the means lays between the two values: between 0.3922 and 0.4463 and we are 95% certain. Specifically, the interpretation of each result according to the APA style of representation is also presented as follows:

In this study, the first hypothesis was there is no significant difference between the mean of the NRPB standard ESD and calculated ESD4.

To test the hypothesis that the means of the NRPB standard ESD values ($M = 0.3000$, $SD = 0.00000$) and the calculated ESD4 values ($M = 0.4945$, $SD = 0.11754$) were equal, a dependent sample t-test was performed. Prior to conducting the analysis, the assumption of normally distributed difference scores was examined. The assumption was considered satisfied, as the Skew and Kurtosis levels were estimated at -0.011 and -0.0990, respectively, which is less than the maximum allowable values for a t-test (i.e., Skew < |2.0| and Kurtosis < |9.0|; Posten, 1984). It will also be noted that the correlation between the two categories was estimated at r = 0.000, p < 0.001, suggesting that the dependent sample t-test is appropriated in this case. The null hypothesis of equal means of the NRPB standard ESD and calculated ESD4 was rejected. Thus, the mean of the calculated ESD4 was statistically significantly higher than the mean NRPB standard ESD. Cohen's d was estimated at 2.158 which is a large effect based on Conhen's (1992) guidelines. A graphical representation of the means and adjusted 95% confidence interval is displayed in Figure 2.

The second hypothesis was there is no significant difference between the mean of the UNSCEAR standard ESD and calculated ESD4.

To test the hypothesis that the means of the UNSCEAR standard values (M = 0.0500, SD = 0.00000) and the calculated ESD values (M = 0.4945, SD = 0.11754) were equal, a dependent sample t-test was performed. Prior to conducting the analysis, the assumption of normally distributed difference scores was examined. The assumption was considered satisfied, as the Skew and Kurtosis levels were estimated at -0.011 and -0.0990, respectively, which is less than the maximum allowable values for a t-test (i.e., Skew < |2.0| and Kurtosis < |9.0|) (Posten ,1984). It will also be noted that the correlation between the two categories was estimated at t = 16.91, p < 0.000, suggesting that the dependent sample t-test is appropriated in this case. The null hypothesis of equal mean of the UNSCEAR standard ESD and calculated ESD4 was rejected. Thus, the mean of the calculated ESD4 was statistically significantly higher than the UNSCEAR standard ESD. Cohen's d was estimated at 2.702 which is a large effect based on Conhen's (1992) guidelines. A graphical representation of the means and adjusted 95% confidence interval is displayed in Figure 3.

The third hypothesis was there is no significant difference between the mean of the IAEA standard ESD and calculated ESD4.

To test the hypothesis that the means of the IAEA (2007) standard values (M = 0.2000, SD = 0.00000) and the calculated ESD4 values (M = 0.4945, SD = 0.11754) and were equal, a dependent sample t-test was performed. Prior to conducting the analysis, the assumption of normally distributed difference scores was examined. The assumption was considered satisfied, as the Skew and Kurtosis levels were estimated at -0.011 and -0.0990, respectively, which is less than the maximum allowable values for a t-test (i.e., Skew < |2.0| and Kurtosis < |9.0|) (Posten 1984). It will also be noted that the correlation between the two categories was estimated at r = 0.000, p < 0.001, suggesting that the dependent sample t-test is appropriated in this case. The null hypothesis of equal mean of the IAEA standard ESD and calculated ESD4 was also rejected. Thus, the mean of the calculated ESD4 was statistically significantly higher than the mean IAEA standard ESD. Cohen's d was estimated at 1.348 which is a large effect based on Conhen's (1992) guidelines. A graphical representation of the means and adjusted 95% confidence interval is displayed in Figure 4.

Table 8, 9 and 10 shows the analysis of the mean and adjusted mean values of the standard ESD values for UNSCEAR (2000), IAEA (2007) and NRPB (2000) with that of calculated ESD4 values. The error bar graph for the adjusted values shows the differences between the standard and the calculated ESDs using the grand mean value of 0.3957 for NRPB, 0.3457 for UNSCEAR and 0.2707 for IAEA are shown in Figure 2, 3 and 4. The analysis of the error bars using the means were carried out by first finding the mean for the calculated value of ESD and the standard values. The standard ESD mean values was subtracted from the calculated ESD mean values to find the adjustment, then finally the error bar was plotted. This method was repeated for all the regulatory bodies under study.

Table 8: Mean and Adjusted Mean for ESD4 and NRPB

S/N	NRPB	ESD4	Difference	Mean	Adjustment	NRPB_Adj	ESD_Adj
1.	0.30	0.56	0.26	0.43	0.06	0.36	0.62
2.	0.30	0.49	0.19	0.39	0.10	0.40	0.58
3.	0.30	0.38	0.08	0.34	0.15	0.45	0.53
4.	0.30	0.59	0.29	0.44	0.05	0.35	0.63
5.	0.30	0.69	0.39	0.49	0.00	0.30	0.68
6.	0.30	0.44	0.14	0.37	0.12	0.42	0.56
7.	0.30	0.61	0.31	0.45	0.04	0.34	0.64
8.	0.30	0.50	0.20	0.40	0.09	0.39	0.59
9.	0.30	0.63	0.33	0.46	0.03	0.33	0.65
10.	0.30	0.43	0.13	0.36	0.13	0.43	0.55
11.	0.30	0.66	0.36	0.48	0.01	0.31	0.67
12.	0.30	0.33	0.03	0.31	0.18	0.48	0.50
13.	0.30	0.30	0.00	0.30	0.19	0.49	0.49
14.	0.30	0.48	0.18	0.39	0.10	0.40	0.58
15.	0.30	0.49	0.19	0.39	0.10	0.40	0.58
16.	0.30	0.50	0.20	0.40	0.09	0.39	0.59
17.	0.30	0.33	0.03	0.31	0.18	0.48	0.50
18.	0.30	0.44	0.14	0.37	0.12	0.42	0.56
19.	0.30	0.63	0.33	0.46	0.03	0.33	0.65
20.	0.30	0.38	0.08	0.34	0.15	0.45	0.53

Table 9: Mean and Adjusted Mean for ESD4 and UNSCEAR

S/N	UNSCEAR	ESD4	Difference	Mean	Adjustment	UNSCEAR_Adj	ESD_Adj
1.	0.05	0.56	0.51	0.30	0.11	0.16	0.67
2.	0.05	0.49	0.44	0.27	0.15	0.20	0.63
3.	0.05	0.38	0.33	0.22	0.20	0.25	0.58
4.	0.05	0.59	0.54	0.32	0.10	0.15	0.68
5.	0.05	0.69	0.64	0.37	0.05	0.10	0.73
6.	0.05	0.44	0.39	0.24	0.17	0.22	0.61
7.	0.05	0.61	0.56	0.33	0.09	0.14	0.69
8.	0.05	0.50	0.45	0.28	0.14	0.19	0.64
9.	0.05	0.63	0.58	0.34	0.08	0.13	0.70
10.	0.05	0.43	0.38	0.24	0.18	0.23	0.60
11.	0.05	0.66	0.61	0.35	0.06	0.11	0.72

12.	0.05	0.33	0.28	0.19	0.23	0.28	0.55
13.	0.05	0.30	0.25	0.17	0.24	0.29	0.54
14.	0.05	0.48	0.43	0.27	0.15	0.20	0.63
15.	0.05	0.49	0.44	0.27	0.15	0.20	0.63
16.	0.05	0.50	0.45	0.28	0.14	0.19	0.64
17.	0.05	0.33	0.28	0.19	0.23	0.28	0.55
18.	0.05	0.44	0.39	0.24	0.17	0.22	0.61
19.	0.05	0.63	0.58	0.34	0.08	0.13	0.70
20.	0.05	0.38	0.33	0.22	0.20	0.25	0.58

Table 10: Mean and Adjusted Mean for ESD4 and IAEA

S/N	IAEA	ESD4	Difference	Mean	Adjustment	IAEA_Adj	ESD_Adj
1.	0.20	0.56	0.36	0.38	0.19	0.39	0.74
2.	0.20	0.49	0.29	0.34	0.22	0.42	0.71
3.	0.20	0.38	0.18	0.29	0.27	0.47	0.66
4.	0.20	0.59	0.39	0.39	0.17	0.37	0.76
5.	0.20	0.69	0.49	0.44	0.12	0.32	0.81
6.	0.20	0.44	0.24	0.32	0.25	0.45	0.68
7.	0.20	0.61	0.41	0.40	0.16	0.36	0.77
8.	0.20	0.50	0.30	0.35	0.21	0.42	0.72
9.	0.20	0.63	0.43	0.41	0.15	0.35	0.78
10.	0.20	0.43	0.23	0.31	0.25	0.45	0.68
11.	0.20	0.66	0.46	0.43	0.14	0.34	0.79
12.	0.20	0.33	0.13	0.26	0.30	0.50	0.63
13.	0.20	0.30	0.10	0.25	0.32	0.52	0.61
14.	0.20	0.48	0.28	0.34	0.22	0.42	0.71
15.	0.20	0.49	0.29	0.34	0.22	0.42	0.71
16.	0.20	0.50	0.30	0.35	0.21	0.42	0.72
17.	0.20	0.33	0.13	0.26	0.30	0.50	0.63
18.	0.20	0.44	0.24	0.32	0.25	0.45	0.68
19.	0.20	0.63	0.43	0.41	0.15	0.35	0.78
20.	0.20	0.38	0.18	0.29	0.27	0.47	0.66

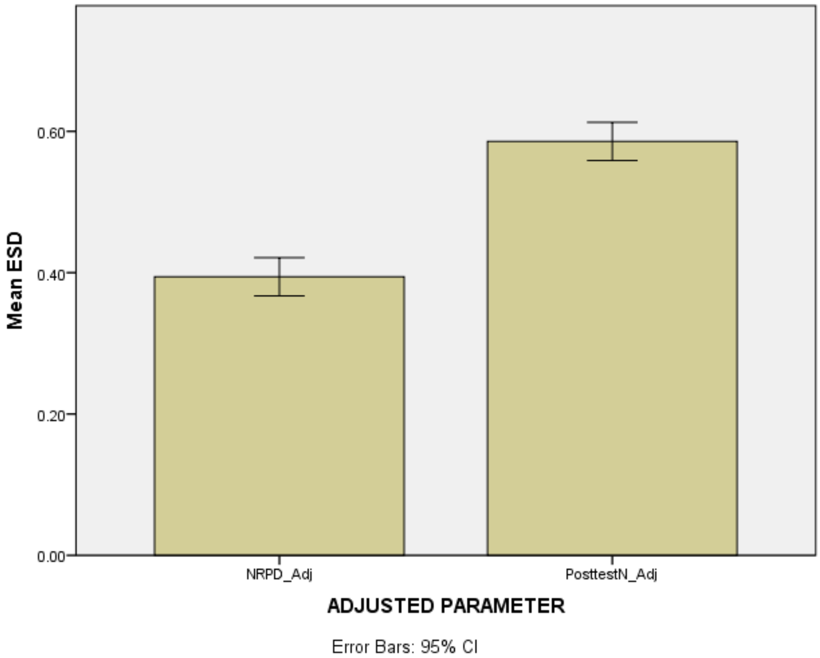

Figure 2: Error Bars with Adjusted 95% Confidence Interval for NRPB

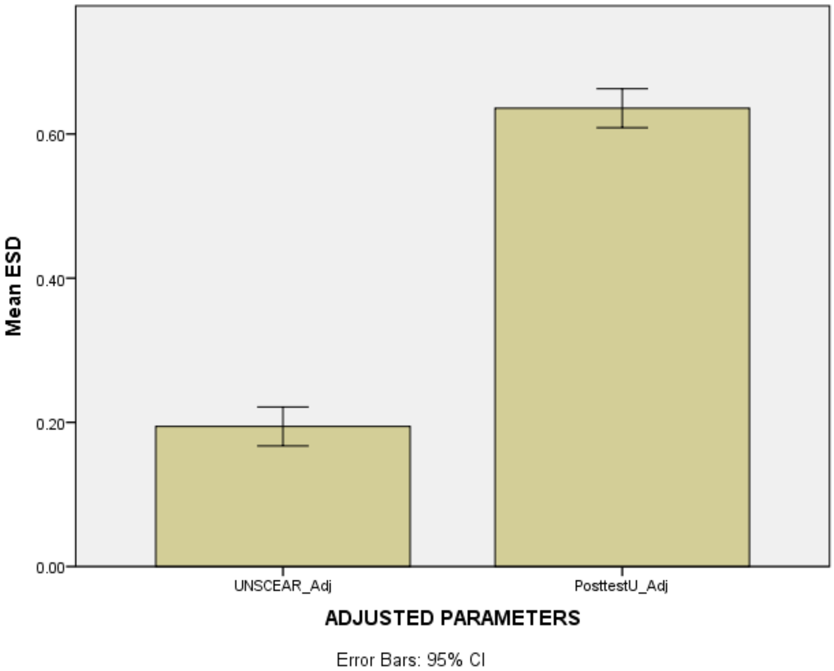

Figure 3: Error Bars with Adjusted 95% Confidence Interval for UNSCEAR

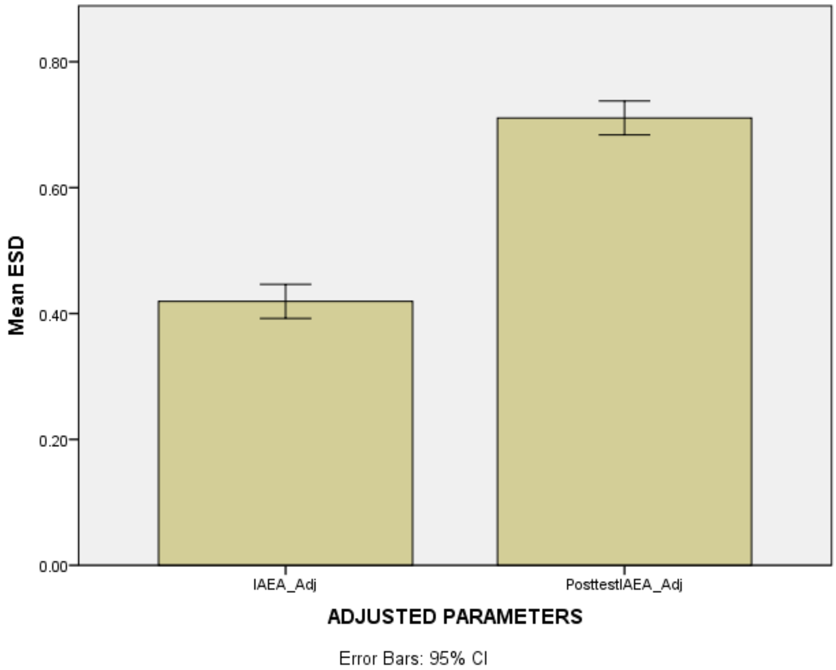

Figure 4: Error Bars with Adjusted 95% Confidence Interval for IAEA

3.1. Discussion

The findings of the study revealed that 50% of the sampled diagnostic centres under study showed positive misalignment beyond the normal limit of 2% while 50% showed beam alignment within the normal limit. The misalignment ranged from 1.6% to 3.4% and 1.4% to 2.6% across and along the cassette respectively. This finding is in line with Al-Jasim *et al.* (2017) who obtained a mean misalignment across the cassette as 0.4% using beam alignment test tool in Baghdad, Iraq. Also in line with Ike-Ogbonna *et al.* (1996) who obtained a 50% X-ray beam alignment compliance using Gammex beam alignment test tool in Plateau State, Nigeria. This finding is also in line with other researchers reviewed in this study such as Carlin *et al.* (1996) and Brookfield *et al.* (2015). But this finding is not in line with the finding of Begum *et al.* (2011) who obtained a mean percentage misalignment value of 60% using the same beam alignment measuring method in Bangladesh. Also, the findings is not in line with Okeji *et al.* (2016) who obtained a mean percentage misalignment value of 79% using simple locally test kit in Enugu, Nigeria. This could be attributed to the non-standardization of the locally sourced test kits used by the researcher as well as non-adherence of some diagnostic centres to carry out routine regular quality control test as it is expected of them.

The findings on the calculated mean values of ESD compared with diagnostic reference level (DRL) recommended values and guide levels by UNSCEAR (2000), IAEA (2007) and NRPB (2000) references for chest PA/LAT projection reveals that the mean ESD value of 0.27mGy recorded at diagnostic centre XDC3 is in line with the recommended guide levels of 0.30mGy, 0.05mGy and 0.20mGy respectively as recommended by the above listed internationally recognized regulatory agencies while the mean ESD value of 0.49mGy as recorded at diagnostic centre XDC4 is not in line with the values as recommended by the internationally recognized regulatory agencies.

By implication, it means that the radiation beam exposure from the X-ray machine at diagnostic centre XDC3 is optimally working properly and functionally well while the X-ray machine at diagnostic centre XDC4 may be faulty and needs routine quality control tests to be performed on it as this may cause over exposure of patients to unnecessary radiation.

In order to find out the difference of ESDs of the standard and calculated values, a descriptive statistics for the variable, paired samples correlations, and paired t-test was used. From the SPSS statistics of pair samples dependent T-test, a p-value of $p < 0.000$ was recorded, therefore, hypothesis one to three that there is no significant difference between the calculated mean value of ESD4 and all the standard values were rejected, because the differences were all statistically significant at p-value < 0.0001. However in attempt to compare this finding with previous work done, it appears that of all the previous work reviewed in this study, none of the study was able to carried out a paired sample t-test to ascertain whether the difference between the standard and calculated values of their results were significant or not, as such this forms part of the contribution of this study to the existing literature.

4. Conclusion

This study reveals the need for quality assurance programmes to be developed and effected in all the radiological facilities across the city of Abuja. The light beam diaphragm in the selected diagnostic centres under study were unable to maintain the relationship between the light field and X-ray field giving rise to misalignment in the X-ray beam. These can adversely result to overexposure to radiation dose by patients during medical examinations.

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