International Journal of Innovative Medicine & Medicinal Plants Research
14(1):53-59, Jan.-Mar., 2026

 www.seahipublications.org ISSN: 2467-8538

doi:10.5281/zenodo.18767408

Measurement of X-Ray Beam and Light Field Alignment of Some Selected Hospitals in Jos, Plateau State, Nigeria

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ABSTRACT

Accurate alignment of the X-ray beam with the light field is critical for optimizing radiation dose and ensuring high diagnostic image quality in radiography. Inadequate beam alignment may result in unnecessary patient exposure, repeat examinations, and compromised diagnostic accuracy. This study evaluated the beam alignment performance of five diagnostic X-ray facilities in Jos, Plateau State, Nigeria.Beam alignment quality control tests were conducted by assessing the congruence between the visually defined field and the X-ray field, field size accuracy, alignment between the centre of the X-ray field and the Bucky, and centring between the X-ray beam and the light field. Measured values were compared with tolerance limits recommended by the American Association of Physicists in Medicine (AAPM).The results showed that three facilities (R1, R2, and R5) satisfied all four quality control tests, with deviations within the acceptable tolerance limit of 2% of the focus-to-film distance, representing a 60% pass rate. Two facilities (R3 and R4) failed at least one beam alignment parameter, indicating non-compliance with recommended standards.

These findings demonstrate variability in beam alignment performance among diagnostic X-ray facilities in the study area and highlight the importance of routine quality control testing, proper equipment maintenance, and adherence to established standards to enhance radiation safety and diagnostic image quality.

Keywords: X-ray Beam Alignment, Quality Control, Diagnostic Radiology, Radiation Protection, Image Quality.

INTRODUCTION

Radiography is an essential diagnostic tool in modern medicine. Among the various imaging modalities, the X-ray machine remains the most widely used due to its ability to provide rapid, cost-effective, and reliable diagnostic information. Consequently, X-ray examinations often serve as the first line of investigation in many healthcare facilities, ranging from large teaching hospitals to small diagnostic centres.

Despite its widespread clinical utility, diagnostic X-ray imaging is associated with potential radiation risks. Improper use of X-rays can result in biological damage due to their ionizing nature, posing hazards to both patients and healthcare workers (Hashemi et al., 2019). In addition, X-ray images must meet a minimum acceptable level of quality to minimize diagnostic errors and allow accurate interpretation while maintaining radiation doses as low as reasonably achievable. To achieve this balance, the American Association of Physicists in Medicine (AAPM) recommends the implementation of a comprehensive quality assurance (QA) programme in radiological practice (Mohammed et al., 2020).

Quality assurance and quality control (QC) programmes are critical for ensuring accurate diagnostic information at optimal radiation doses (AAPM, 2002; IAEA, 2017; WHO, 1982). One of the key components of QC in diagnostic radiology is proper beam alignment. Beam alignment ensures congruence between the X-ray field, the light field, and the image receptor. Previous studies have shown that light beam diaphragm misalignment significantly increases patient radiation dose during routine radiographic examinations (Brookfield et al., 2015). Inadequate beam alignment can lead to irradiation of tissues outside the region of clinical interest, increased scatter radiation, repeat examinations, and compromised image quality. The X-ray beam-limiting device therefore plays a significant role in reducing radiation dose to patients, radiation workers, and the general public by restricting the radiation field to the area of interest (Ike-Ogbonna et al., 2017).

Beam alignment and collimation practices have been widely investigated as essential radiation protection measures. Okeji and Anakwue (2010) evaluated X-ray beam collimation practices among radiographers and reported that inadequate collimation significantly contributes to unnecessary patient radiation exposure during routine radiographic examinations. Their findings emphasize the crucial role of radiographers in ensuring effective beam restriction as part of radiation safety practice.

In digital radiography, improper collimation remains a concern despite technological advancements. Bomer et al. (2015) examined electronic collimation in pediatric digital radiography and reported that electronic cropping often conceals poor initial beam collimation. Their study demonstrated that reliance on electronic collimation implies that the original radiation field was larger than required, resulting in unnecessary radiation exposure, particularly among pediatric patients.

Quality control assessments in diagnostic radiology have revealed variability in equipment performance across facilities. Begum et al. (2011) conducted performance testing of diagnostic X-ray units in Bangladesh using standardized QC protocols and reported that several facilities failed to meet acceptance limits for beam alignment and field congruence, among other parameters. These findings underscore the importance of routine QC testing to ensure compliance with recommended standards and safeguard patient safety.

In Nigeria, the lack of routine QC practices in diagnostic radiology has been well documented. Aweda (2001) reported that many X-ray machines in Nigeria are installed and commissioned with limited consideration for radiation protection and safety requirements. Similarly, Okeji et al. (2016) assessed the status of light beam diaphragms in government and private radiology centres in Enugu State and found that misalignment and malfunctioning of beam-limiting devices were common, potentially contributing to increased population radiation dose.

Jos North Local Government Area, like many parts of Plateau State, has experienced increased establishment of public and private diagnostic X-ray centres. While this expansion has improved access to imaging services, it also raises concerns regarding the adequacy of quality assurance and beam alignment practices in these facilities. There is limited documented evidence on the beam alignment status of X-ray machines operating within the area.

This study therefore aims to evaluate the beam alignment of X-ray machines in five selected diagnostic centres in Jos North Local Government Area, Plateau State. The findings are expected to provide insight into current quality control practices and support evidence-based recommendations for improving radiation safety and diagnostic image quality in the region.

METHODOLOGY

Measurement for misalignment

I. X-ray machines from five (5) X-ray centres were evaluated for their beam alignment accuracies over a two months period in 2025.
II. The X-ray film was loaded into the cassette and placed on the X-ray table/Bucky.
III. With the X-ray table leveled, the central ray at 90° was focusedon the centre of the cassette on the tabletop/ Bucky.
IV. A Film Focus Distance (FFD) of 100 cm was then set.
V. The collimator light was then switched on.
VI. With the centre of the X-ray tube coinciding with the centre of the loaded cassette, a light field size of 20 x 20cm was collimated within the edge of the cassette, leaving a border all around that is outside of the light field.
VII. The eight coins were placed in pairs, so that where the coins touch, coincides with the edge of the light area and the ninth coin was placed as marker.
VIII. An exposure using 60kVp and 15 mAs that will give the adequate optical density was then made.
IX. The film was then developed using the digital processor and inspected on a computer screen.
X. To determine misalignment of the visually defined field with respect to the X-ray field is shown in figure 3 below.

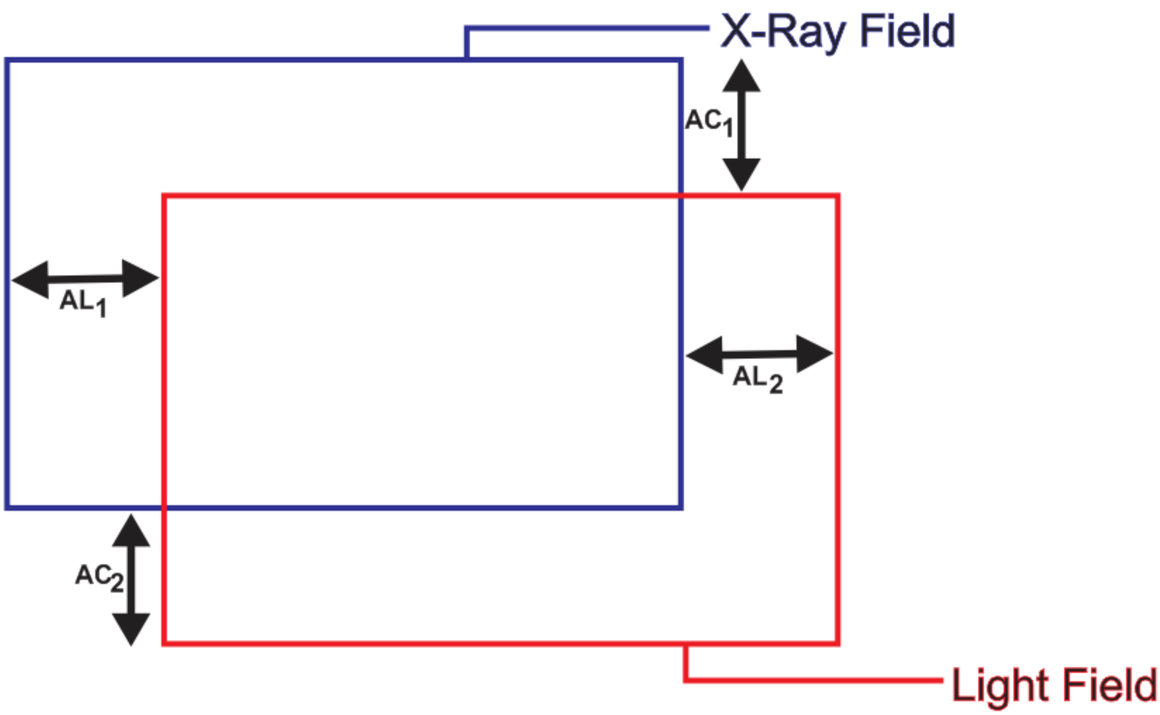

Figure 3: The Displacement of the X-Ray Field with Respect to the Light Field.

Measurement for misalignment was carried out as follows: Misalignment across the cassette (AC_1 and AC_2) and along the cassette (AL_1 and AL_2) of the film was added and recorded as total misalignment for AC and AL respectively. Percentage misalignment across (AC) and along (AL) the film was calculated by dividing the total misalignment by the focus to film distance and multiplied by 100 as shown in Equation (1) and (2) (Okeji*et al*., 2016).

$$AC\% = \frac{Total\ AC}{FFD} X\ 100 \ldots \ldots \ldots \ldots \quad 1.$$

$$AL\% = \frac{Total\ AL}{FFD}\ X\ 100 \ldots \qquad 2.$$

If the sum of the displacement across the length or the width, that is, (AC_1 +AC_2) or (AL_1+AL_2) is greater than 2cm (2% of 100 cm) of the length or width away from the light field margin, the X-ray machine must be serviced.

XI. To determine the variation between the X-ray field size dimensions at 1m as defined by the beam limiting device. The dimension of the X-ray image (actual area) was measured and the deviation from set area of the collimated light field as adjusted by the beam limiting device i.e. 20cm x 20cm as indicated on the exposed film was evaluated using Equation 3below.

$$DEVIATION\% = \frac{MEASURED\ AREA - SET\ AREA}{SET\ AREA}\ X\ 100 \ldots \qquad 3.$$

The Deviation must be ≤ ± 2cm at 1 m FFD (i.e. 2% of the FFD).

XII determine the X-ray/light beam centring. A line was drawn from corner to corner of the X-ray image and a similar corner to corner lines drawn of the light field with the two lines crossing to mark the centre points see Figure 4 below.

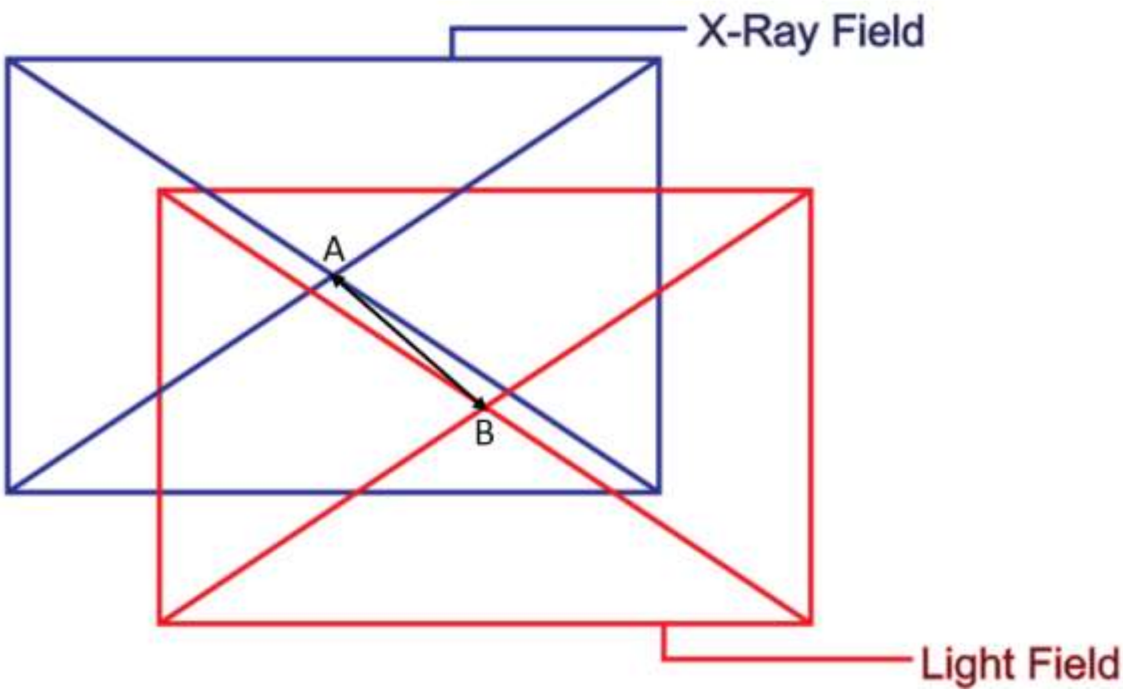

Figure 4: The X-Ray Beam and Light Beam Centre Displacement.

The distance from the points of interceptions A and B was then measured and the percentage displacement were calculated using Equation 5 below.

$$AL\% = \frac{AO}{FFD}\ X\ 100 \ldots \qquad 4.$$

AO: This is the distance between the centre of the X-ray field and the centre of the light field on the film or image receptor. It shows how much the two centres are out of line with each other. This distance (AO) should be ≤ ±2% of the set FFD.

XIII. The alignment of the centre of the X-ray field and the centre of the Bucky. Similar procedure was taken as in step-I to step-X above, however, the loaded cassette was placed in the Bucky. Determine the alignment of the centre of the X-ray field and the centre of the Bucky by employing step **XII**.

RESULTS

The results of this study, comprising X-ray field and light field assessments of five X-ray facilities, are shown below.

Plate 1: Position Of Coins on Radiographic Image Detector/Film

Plate 2: Radiographic Image of Coins

Table 1: Congruence between the X-ray field and Light Field

X-RAY FACILITY	LEFT SHIFT (AL1)(cm)	RIGHT SHIFT(AL_2)(cm)	TOP SHIFT (AC_1)(cm)	BOTTOM SHIFT (AC_2)(cm)	TOTAL VERTICAL SHIFT(cm)	TOTAL HORIZONTAL SHIFT(cm)
R1	0.10	0.20	0.20	0.30	0.50	0.30
R2	0.10	0.10	0.10	0.10	0.20	0.20
R3	0.40	0.40	0.40	0.80	1.20	0.80
R4	1.35	0.65	0.70	0.1	0.80	2.0
R5	0.20	0.40	0.10	0.20	0.30	0.60

Table 2*:* Congruence between the X-ray field and Light Field Size Dimension At 1m

X-RAY FACILITY	SET FIELD SIZE(cm)	MEASURED FIELD SIZE(cm)	SET FIELD AREA(cm^2)	MEASURED AREA(cm^2)	DEVIATION(cm^2)
R1	20 X 20	19.95 x 20.00	400	399.0	0.0025(0.25%)
R2	20 X 20	19.97 x 19.98	400	399.0	0.0023(0.23%)
R3	20 X 20	19.97 x 19.91	400	397.6	0.0059(0.50%)
R4	20 X 20	18.20 x 18.43	400	335.4	0.6100(16.00%)
R5	20 X 20	20.00 x 20.30	400	406.0	0.0158(1.60%)

Table 3: Alignment of the Centre of the X-ray Field and the Centre of the Bucky

X-RAY FACILITY	DEVIATION (cm)
R1	0.26 (0.26%)
R2	0.20 (0.20%)
R3	3.0 (3.0%)
R4	1.1 (1.1%)
R5	0.3 (0.3%)

Table 4: Alignment of the Centre of The X-ray Field and the Centre of the Light Beam.

X-RAY FACILITY	DEVIATION (cm)
R1	0.24 (0.24%)
R2	0.17 (0.170%)
R3	2.90(2.90%)
R4	3.51 (3.51%)
R5	0.30 (0.30%)

DISCUSSION

This study focuses mainly on the evaluation of the X-ray field and light field alignment of five selected X-ray centres in Jos, Plateau State by evaluating the misalignment test between the visually defined field and the X-ray field, the deviation between the set field size and the measured field size dimensions, the displacement between the Centre of the X-ray field and the Centre of the Bucky and the displacement between the X-ray field and light beam centring. From the result of this study only R1, R2 and R5 (where R is the X-ray centres used) were able to pass the four checks having values below the AAPM set limit of 2% of the FFD. This represents a 60% compliance rate among the evaluated facilities. R3 and R4 both failed at least one of the four tests, hence, failed the beam limiting device Quality control test.The observed failures were attributed primarily to poor equipment maintenance, inadequate calibration, and aging or refurbished machines lacking routine quality control checks. These findings are consistent with previous studies reporting higher misalignment rates in poorly maintained X-ray systems. The implications of such misalignments include increased patient radiation dose, compromised image quality, repeat examinations, and violation of the ALARA principle.

CONCLUSION

The findings of this study underscore the need for regular quality control (QC) testing be instituted in all radiology departments to ensure beam alignment and collimation remain within international standards. Facilities that failed one or more tests (R3 and R4) should undergo urgent servicing and recalibration of their beam limiting devices to minimize misalignment and unnecessary patient exposure. Radiographers should also receive continuous professional training on equipment use, collimation, and the significance of beam alignment for both radiation safety and image quality. Furthermore, hospital management should enforce preventive maintenance schedules for X-ray machines rather than waiting for faults to appear. Finally, regulatory bodies should strengthen compliance monitoring and impose penalties on facilities that fail to adhere to established quality assurance standards.

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