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Comparative Evaluation of Radiation Emission between Wall Mounted and Handheld Xray Devices Using Dosimetry

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ABSTRACT

Background: Dental radiography is essential for diagnostic and endodontic procedures, yet repeated exposure poses occupational risks for dental practitioners. The increasing use of handheld X-ray devices has raised concerns regarding operator safety due to proximity to the radiation source. Comparative clinical data evaluating radiation emission from handheld versus wall-mounted devices remain limited.

Aim: To comparatively evaluate the radiation emission of a wall-mounted intraoral X-ray machine and two handheld dental X-ray devices using Thermoluminescent Dosimetry (TLD) under routine clinical conditions.

Materials and Methods: This clinical observational study was conducted in the Department of Conservative Dentistry and Endodontics, Guru Nanak Dev Dental College and Research Institute, Sunam, and registered under CTRI/2024/05/074342. A total of 900 intraoral periapical radiographs were obtained using three devices: Alerio Optima wall-mounted unit, Orikam Eighteeth Hyperlight handheld machine, and Runyes Unicorn handheld X-ray machine (300 radiographs each). Exposure time was standardized at 0.20 seconds. Operator radiation exposure was measured using chest-mounted $CaSO_4$:Dy TLD badges, with separate dosimeters for each device. Estimated annual minimum and maximum radiation exposure values were calculated based on daily usage. Statistical analysis was performed using SPSS version 25, and normality was assessed using Kolmogorov–Smirnov and Shapiro–Wilk tests.

Results: All devices recorded a mean operator exposure of 0.00 μSv on TLD badges. However, estimated annual exposure varied across machines. The Orikam handheld device exhibited the widest exposure range (8.82–70.59 μSv), followed by the Alerio wall-mounted unit (13.33–66.67 μSv). The Unicorn handheld device demonstrated the lowest maximum expected annual exposure (27.27 μSv). Normality testing revealed significant deviation from normal distribution (K–S $p=0.005$; S–W $p=0.001$). Daily usage was highest for the Unicorn device (15 exposures/day), followed by Orikam (14/day) and Alerio (12/day).

Conclusion: Although operator-level TLD readings remained negligible for all devices, handheld X-ray machines demonstrated greater variability in estimated annual radiation emission compared to the wall-mounted unit. Model-specific differences were evident, with the Unicorn handheld device showing comparatively lower radiation output. Strict adherence to radiation safety protocols ensures that occupational exposure remains within safe limits, even with handheld radiography systems.

Keywords: Handheld X-ray device, Wall-mounted X-ray, Dosimetry, Thermoluminescent Dosimeter (TLD), Radiation exposure, Endodontics

INTRODUCTION:

Dental radiography remains an indispensable diagnostic tool in contemporary clinical practice, particularly in the field of Conservative Dentistry and Endodontics, where accurate visualization of tooth morphology, periapical tissues, and root canal anatomy is essential for diagnosis, treatment planning, and procedural evaluation. Intraoral periapical radiographs continue to be one of the most frequently prescribed imaging modalities, contributing substantially to the cumulative radiation exposure received by both patients and dental healthcare providers. Although the effective radiation dose from a single intraoral radiograph is relatively low, the repeated and routine nature of dental radiographic procedures makes occupational radiation exposure an important area of focus in dental radiology and radiation protection research. Traditionally, wall-mounted intraoral X-ray units have been the standard equipment used for intraoral radiography. These machines are fixed in position, electrically stable, and designed with regulated beam collimation and filtration systems, thereby providing predictable radiation output. The operator typically maintains a safe distance or uses protective barriers during exposure, ensuring minimal occupational exposure. With advancements in dental technology, however, handheld portable X-ray devices have emerged as attractive alternatives. These devices provide mobility, convenience, and improved workflow efficiency, particularly in clinical situations requiring bedside imaging, treatment in remote locations, community camps, or settings with limited infrastructure. Their compact design and ease of operation have resulted in widespread adoption across private practices, dental colleges, and outreach settings.

Despite their advantages, handheld X-ray devices have raised increasing concerns regarding radiation safety. Unlike wall-mounted units, handheld devices require the operator to hold the device during exposure, theoretically placing them closer to the primary beam and subjecting them to increased scatter radiation. While manufacturers claim that modern handheld machines are equipped with internal shielding, backscatter reduction mechanisms, and optimized beam direction systems, several studies have reported conflicting findings regarding the actual radiation output and operator-level exposure associated with handheld units. The variation in tube voltage, current, exposure time, inherent filtration, device positioning, and operator technique further complicates the interpretation of their dosimetric safety. The biological effects of ionizing radiation, even at low doses, are well documented. The cumulative dose, rather than the dose per procedure, determines long-term risks, including stochastic effects such as carcinogenesis. For dental practitioners who perform hundreds of radiographic procedures annually, understanding the comparative exposure risk associated with different radiographic devices is imperative. International radiation safety guidelines consistently emphasize the principles of ALARA (As Low As Reasonably Achievable), justification of exposure, optimization of technique, and the use of protective barriers. In this context, evaluating whether handheld X-ray devices meet the same safety benchmarks as conventional wall-mounted units becomes a matter of both scientific interest and clinical importance.

Previous investigations into handheld dental X-ray devices have reported varying levels of radiation exposure depending on machine design, operator handling, device orientation, and the presence of external backscatter shields. However, many of these studies have been conducted under controlled laboratory conditions rather than real clinical scenarios, limiting their generalizability. Furthermore, limited studies have employed direct operator-worn dosimetry devices such as Thermoluminescent Dosimeters (TLDs), which remain the gold standard for measuring occupational exposure. As a result, significant gaps persist in understanding the practical differences in radiation emission between handheld and wall-mounted devices during routine clinical procedures. Another critical aspect that remains insufficiently explored is the variation in radiation emission across different brands and models of handheld X-ray units. With the rapid expansion of dental equipment manufacturers, devices differ widely in terms of build quality, technical specifications, frequency output, filtration characteristics, and exposure parameters—all of which influence radiation safety.

There is a pressing need to evaluate whether these devices meet recommended safety standards when used by clinicians in routine endodontic practice.

The increasing dependence on radiographic guidance during endodontic procedures, especially root canal treatment, further intensifies the relevance of this investigation. In a typical endodontic case, multiple radiographs may be required to assess working length, canal morphology, obturation adequacy, and postoperative outcomes. Therefore, a systematic comparison of radiation emission from commonly used handheld devices versus a standard wall-mounted unit becomes crucial for developing evidence-based guidelines and improving radiation safety protocols in clinical settings. Given these considerations, the present study was designed to comparatively evaluate the radiation emission of a conventional wall-mounted X-ray machine and two different handheld X-ray devices using Thermoluminescent Dosimetry under real clinical conditions. By analyzing annual expected radiation exposure, radiation variability, and operator-level exposure, this study aims to provide reliable evidence on whether handheld units pose an elevated radiation risk to operators compared to traditional systems. The findings are expected to support clinicians, educators, and regulatory authorities in making informed decisions regarding the safe and appropriate use of handheld dental X-ray devices.

Aim and Objectives

Aim

To comparatively evaluate the radiation emission of a wall-mounted X-ray machine and two handheld dental X-ray devices using Thermoluminescent Dosimetry (TLD) under routine clinical conditions during endodontic procedures.

Objectives

1. To measure and compare the radiation exposure emitted by:
    - Alerio Optima Wall-Mounted X-ray Unit
    - Orikam Eighteeth Hyperlight Handheld X-ray Device
    - Runyes Unicorn Handheld X-ray Device
2. To assess the estimated minimum and maximum annual radiation exposure for each X-ray device based on clinical usage frequency.
3. To evaluate operator-level radiation exposure using chest-mounted Thermoluminescent Dosimeter (TLD) badges during routine radiographic procedures.
4. To determine whether handheld X-ray devices pose a higher occupational radiation risk compared to the conventional wall-mounted unit.
5. To analyze the normality and distribution of radiation exposure data and apply appropriate statistical methods for comparison among groups.
6. To provide evidence-based recommendations on the safe and efficient use of handheld dental X-ray machines in clinical endodontic practice.

METHODOLOGY

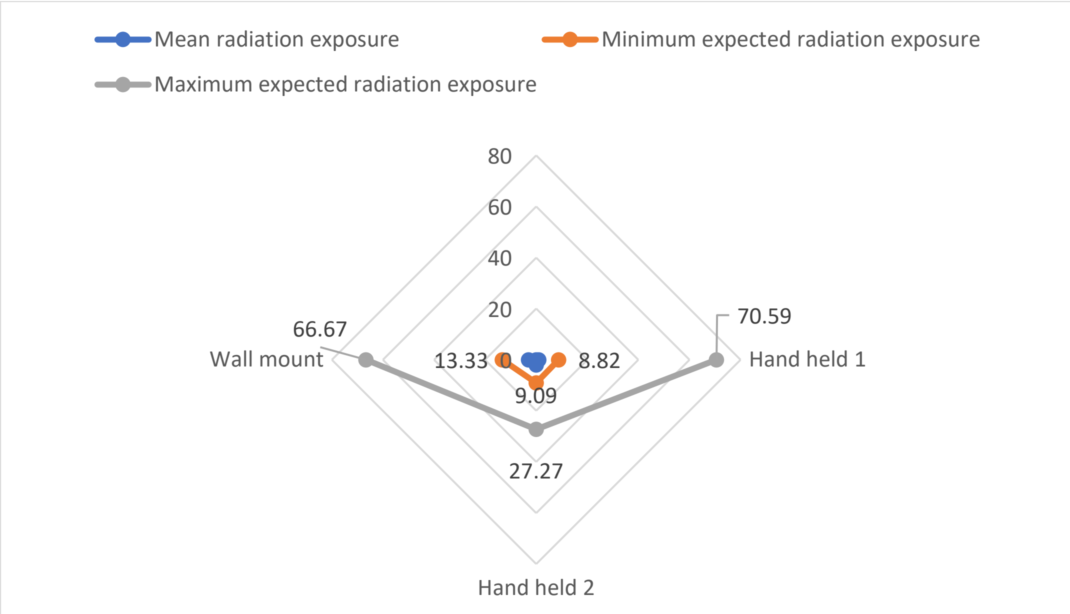
This comparative observational study was conducted in the Department of Conservative Dentistry and Endodontics at Guru Nanak Dev Dental College and Research Institute, Sunam, and was prospectively registered under the Clinical Trials Registry–India (CTRI/2024/05/074342). A total of 900 intraoral periapical radiographs were obtained from patients undergoing root canal treatment of mandibular molars. The sample size for the study was calculated using G*Power 3.1 software with a power of 80% and an alpha error of 5%. An effect size of 0.21, derived from a previous study by Joel E. Grey et al. (2012), served as the basis for computation, considering the reported mean radiation dose of 0.51 µSv for handheld devices and 6.04 µSv for wall-mounted units, with a pooled standard deviation of 1.03. A one-way ANOVA (fixed effects, omnibus, a priori) model determined that a minimum of 225 radiographs (75 per group) was required; however, 900 radiographs (300 per group) were collected to increase the robustness of the analysis. The study population consisted of systemically healthy individuals undergoing root canal treatment, with adequate mouth opening and cooperation for radiographic procedures and no known allergies to endodontic materials such as rubber dam components or local anesthetics. Patients below 18 years or above 60 years of age, medically compromised individuals, and pregnant women were excluded from the study. Radiographs were taken using three different dental X-ray devices: the Alerio Optima wall-mounted unit operating at 200 kHz, 65 kV DC, and 7 mA; the Orikam Eighteeth Hyperlight handheld unit operating at 50–60 Hz, 65 kV, and 2.5 mA; and the Runyes Unicorn handheld device operating at 50–60 Hz, 70 kV, and 2.0 mA. For standardization, the exposure time was fixed at 0.20 seconds for all machines. The radiographs were divided equally, with 300 exposures taken using each machine.

Throughout the procedure, strict radiation safety protocols were followed. The operator wore a 0.50 mm Pb-equivalent lead apron measuring 100 × 60 cm and a thyroid collar. A chest-mounted Thermoluminescent Dosimeter (TLD) badge containing $CaSO_4$:Dy Teflon discs, with a measuring range of 0.05–10 mSv, was placed on the left side outside the lead apron to record operator-level radiation exposure. To prevent cross-contamination of readings, separate TLD badges were used for each X-ray machine. Patients were seated upright during all radiographic procedures, with the occlusal plane parallel and the midsagittal plane perpendicular to the floor, ensuring reproducible head positioning. The paralleling technique was used for all radiographs to maintain consistency, with the X-ray beam directed perpendicular to both the sensor and the long axis of the tooth. A sensor holder was used to standardize the angulation and position of the digital sensor. When using the wall-mounted X-ray machine, the operator stood behind a protective lead-lined barrier measuring 72 inches in height and 30 inches in width, with a window thickness of 1/16 inch and lead lining ranging from 1 to 3.5 mm. During handheld X-ray exposures, the operator held the device at arm’s length, ensuring the beam remained parallel to the ground and minimizing proximity to the primary beam.

The average number of radiographs taken per day differed across the devices, with 12 exposures per day recorded for the Alerio wall-mounted unit, 14 for the Orikam handheld device, and 15 for the Unicorn handheld device. These values were included in the estimation of expected annual radiation exposure. Dosimetry analysis was conducted at Ultra Tech Laboratories Pvt. Ltd. using a semi-automatic TLD reader, and the recorded radiation values were systematically tabulated for statistical evaluation. All statistical analyses were performed using SPSS version 25. Data were entered into a Microsoft Excel spreadsheet prior to analysis. The normality of the data was assessed using Kolmogorov–Smirnov and Shapiro–Wilk tests, both of which indicated significant deviation from a normal distribution. Accordingly, categorical variables were expressed as frequencies and percentages, whereas continuous variables were expressed as means and standard deviations. Due to the non-normal nature of the data, appropriate non-parametric statistical tests were employed for comparisons between study groups to determine differences in radiation emission among the three X-ray devices.

Results:

GRAPH 1



GRAPH SHOWING EXPECTED MEAN ANNUALRADIATION EXPOSURE (μSv) BY ALL X RAY MACHINES

TABLE 1

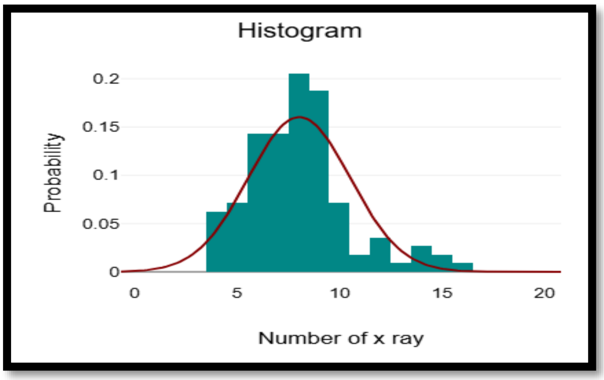
EXPECTED MEAN ANNUAL RADIATION EXPOSURE IN STUDY GROUPS.

The analysis of mean annual radiation exposure across different X-ray machines indicates variability in minimum and maximum expected annual radiation exposure, despite a constant exposure time of 0.2 seconds and nil mean radiation exposure for all machines The Orikam handheld X-ray machine exhibited a maximum expected annual mean radiation exposure of

Group	X-ray machine	Mean radiation exposure Micro-sievert (µSv)	Exposure time (sec)	Minimum expected annual radiation exposure(µSv)	Maximum expected annual radiation exposure(µSv)
Group 1	Alerio Optima(Wall Mount)	0.0	0.2	13.33	66.67
Group 2	Orikam (Hand held)	0.0	0.2	8.82	70.59
Group 3	Unicorn (Hand held)	0.0	0.2	9.09	27.27

70.59 µSv and a minimum of 8.82 µSv, whereas the Unicorn handheld machine showed significantly lower maximum expected annual mean exposure (27.27 µSv) and a slightly higher minimum expected exposure (9.09 µSv) .In comparison, the Alerio Optima wall-mounted X-ray machine recorded the highest expected maximum annual mean exposure (66.67 µSv) and a minimum of 13.33 µSv

GRAPH 2A



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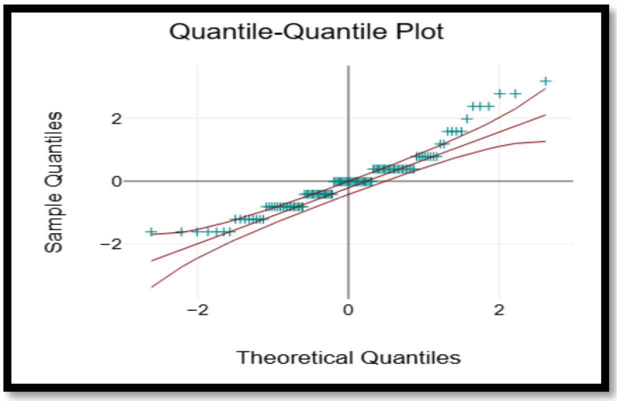
GRAPH 2B

	Statistics	p
Kolmogorov-Smirnov	0.16	0.005
Shapiro-Wilk	0.93	0.001



GRAPHS SHOWING SIGNIFICANT DEVIATION FROM NORMAL DISTRIBUTION

Descriptive analysis

TABLE 2

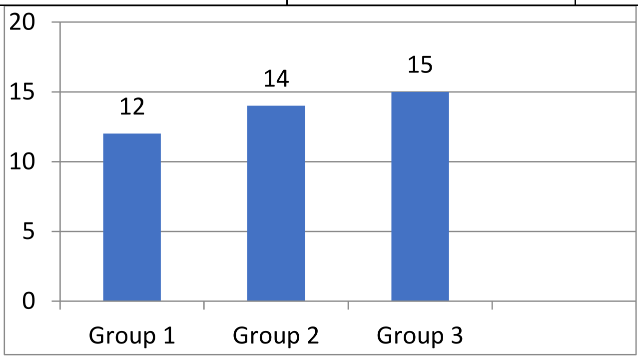
ANALYSIS FOR NORMAL DISTRIBUTION OF DATA

Statistical analysis was done by SPSS software version 25. The data was systematically entered in Microsoft excel sheet. The normality of data was assessed by Shapiro wilk test and non-normal distribution was confirmed by histogram/Q-Q plot. The categorical data were presented as frequency and percentage while continuous data were presented as mean and standard deviation.

The normality analysis of the data using Kolmogorov-Smirnov (KS) and Shapiro-Wilk (SW) tests indicates a significant deviation from normal distribution. The Kolmogorov-Smirnov statistic is 0.16 with a p-value of 0.005, and the Shapiro-Wilk statistic is 0.93 with a p-value of 0.001. Since both p-values are less than the conventional threshold of 0.05, the null hypothesis of normality was rejected. This suggested that the data does not follow a normal distribution.

GRAPH 3

Group	X ray Machine	Average number of X-ray (per day)	Exposure time (Sec)
Group 1	Alerio Optima	12	0.2
Group 2	Orikam	14	0.2
Group 3	Unicorn	15	0.2



AVERAGE NUMBER OF X RAYS PER DAY TAKEN BY EACH STUDY GROUP

TABLE 3

DESCRIPTIVE ANALYSIS OF STUDY GROUPS

The descriptive analysis of X-ray exposure across different study groups reveals variations in the average number of X-rays taken per day while maintaining a consistent exposure time. The Orikam handheld X-ray machine recorded an average of 14 X-rays per day, while the Unicorn handheld machine had a slightly higher usage with 15 X-rays per day. In contrast, the Alerio Optima wall-mounted X-ray machine had the lowest daily usage, with an average of 12 X-rays per day. Despite these variations in frequency, the exposure time remained constant at 0.2 seconds for all three machines, ensuring uniform exposure parameters. The differences in daily X-ray usage could be influenced by factors such as ease of accessibility, operator preference, or clinical workflow.

DISCUSSION

The present study comparatively evaluated the radiation emission patterns of a conventional wall-mounted X-ray machine and two handheld dental X-ray devices using thermoluminescent dosimetry under routine clinical conditions. Although all three machines recorded a mean operator-level exposure of 0.00 μSv on TLD badges, the estimated minimum and maximum annual radiation exposure values demonstrated notable variability among the devices. These findings are consistent with previous research suggesting that while handheld X-ray machines may comply with radiation safety standards, differences in design, shielding, and operator handling can influence the level of scatter radiation and potential occupational exposure.

The Alerio Optima wall-mounted unit demonstrated expected annual exposure values ranging from 13.33 μSv to 66.67 μSv, which aligns with earlier reports indicating that wall-mounted units generally provide stable and predictable radiation output due to fixed positioning, optimized beam collimation, and operator distance during exposure. In contrast, the Orikam handheld device showed the widest exposure range, with a minimum of 8.82 μSv and a maximum of 70.59 μSv. This variation reflects the inherent challenges associated with handheld units, such as differences in device shielding, operator proximity, potential angulation deviations, and the absence of physical barriers. Previous studies by Gray et al. and Jacobs et al. similarly noted that handheld devices may produce higher scatter radiation when not used with appropriate technique and beam direction control.

The Unicorn handheld machine demonstrated the lowest maximum expected annual exposure (27.27 μSv), indicating comparatively stable radiation emission. This may be attributed to its internal shielding efficiency, tube voltage characteristics, and device ergonomics that potentially allow better operator control. Several studies, including those by Farman et al. and Suleiman et al., have highlighted that technological advancements in handheld devices—particularly those incorporating backscatter shields and improved beam restriction—can significantly reduce scatter radiation levels. The present study supports these findings, suggesting that not all handheld devices perform equally, and radiation safety is highly dependent on model-specific engineering features.

The normality analysis of the radiation exposure data revealed significant deviation from normal distribution, as confirmed by both Kolmogorov–Smirnov and Shapiro–Wilk tests. Such non-normal distribution is expected in dosimetric studies where radiation emission values vary according to operator technique, machine output fluctuations, and environmental factors. The necessity of non-parametric statistical methods further emphasizes that radiation exposure data often exhibit variability rather than symmetrical distribution. This reinforces the importance of acquiring a large number of radiographs, as done in the present study, to obtain reliable exposure estimates and strengthen the statistical power.

Another important aspect of this study was the evaluation of daily radiographic workload. Handheld devices—particularly the Unicorn and Orikam machines—were used more frequently than the wall-mounted unit, likely due to enhanced accessibility, reduced setup time, and operator convenience. Increased usage of handheld devices has been observed in previous literature where clinicians prefer portable systems for their flexibility and mobility. However, increased frequency of use also highlights the importance of verifying the cumulative radiation exposure from these devices, as occupational exposure is directly proportional to the number of radiographs taken over a given time period.

Despite the higher expected maximum annual exposure associated with the Orikam handheld machine, the operator-level TLD readings remained negligible across all devices. This supports multiple studies showing that when handheld devices are used correctly—with adequate arm extension, proper beam alignment, and adherence to manufacturer protocols—operator exposure remains well below recommended thresholds. Moreover, the use of lead aprons, thyroid collars, and appropriate positioning further reduces occupational dose, underscoring the importance of rigorous radiation safety protocols.

The strengths of the present study include its real-world clinical setting, use of TLD badges (which remain the gold standard for radiation measurement), evaluation of multiple device brands, and collection of a large sample size that exceeded the minimum statistical requirement. These strengths enhance the validity and applicability of the findings to everyday endodontic practice.

However, certain limitations must be considered. The study measured operator exposure only at chest level, and radiation reaching other body parts—such as hands or eyes—was not assessed. Additionally, environmental factors such as room size, wall reflectivity, and operator movement during handheld exposures may influence scatter radiation but were not individually quantified. Finally, although TLD badges provide cumulative dose assessment, they do not capture moment-to-moment fluctuations in scatter radiation intensity.

Despite these limitations, the study provides valuable insights into the comparative radiation emission of handheld and wall-mounted dental X-ray devices. The findings suggest that while handheld devices may demonstrate greater variability in estimated annual exposure, proper technique and protective measures can ensure occupational exposure remains negligible. Among the handheld devices evaluated, model-specific differences were evident, emphasizing the need for clinicians to consider radiation safety performance—not merely convenience or cost—when selecting portable dental radiography units.

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