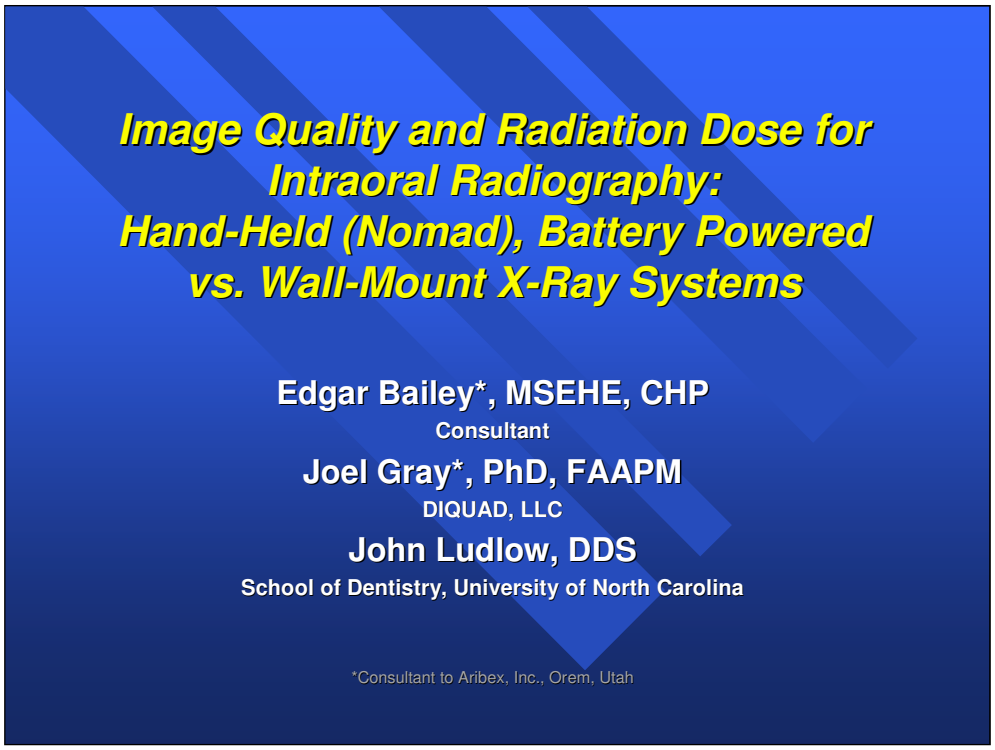


Presented at the
41st Annual Conference on Radiation Control
Conference of Radiation Control Program Directors
Columbus, Ohio
May 18-21, 2009

ABSTRACT

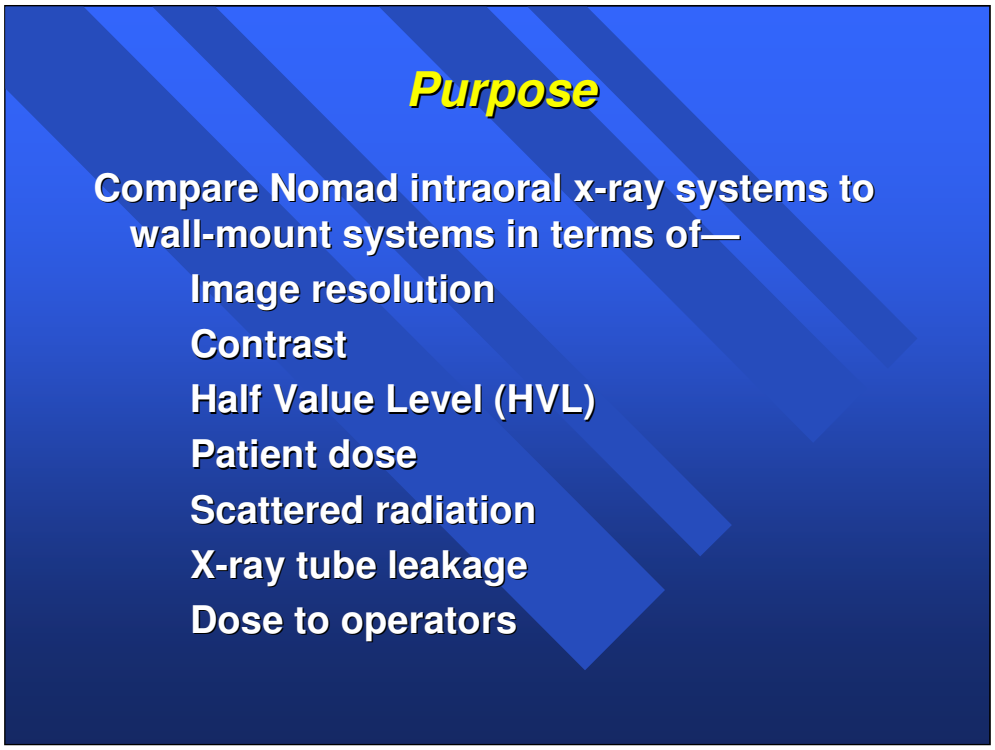
A hand-held, battery-powered dental intraoral x-ray system (60 kV, constant potential output) was compared to a conventional, wall-mounted intraoral x-ray system (70 kVp, self-rectified output) in terms of image quality, and patient and staff radiation doses.

The image quality comparison included quantitative measurements of image sharpness (resolution) and contrast.
Patient doses were compared using the FDA dental phantom and adjusting the radiation dose to obtain the same density on intraoral dental films.

Staff radiation doses were measured using personal dosimetry badges for dental facilities before and after introduction of the hand-held x-ray system allowing accurate comparison of staff doses with both systems under similar workloads and operating conditions.
Results for both image quality, and dose to patients and staff are provided.

INTRODUCTION

The authors apologize for the use of a brand name of a commercial product so frequently. At the onset of this project we were referring to this device as a “hand-held” device. However, other hand-held devices are coming into the market place. These new devices may vary significantly from the device evaluated.



INTRODUCTION

This paper compares the Nomad (Aribex, Orem, Utah) intraoral x-ray system to conventional, wall-mounted systems in terms of image resolution and contrast, the half-value layer (HVL) of the beam, patient dose, scattered radiation, x-ray tube leakage, and dose to the operators.

MATERIALS AND METHODS

SYSTEMS COMPARED

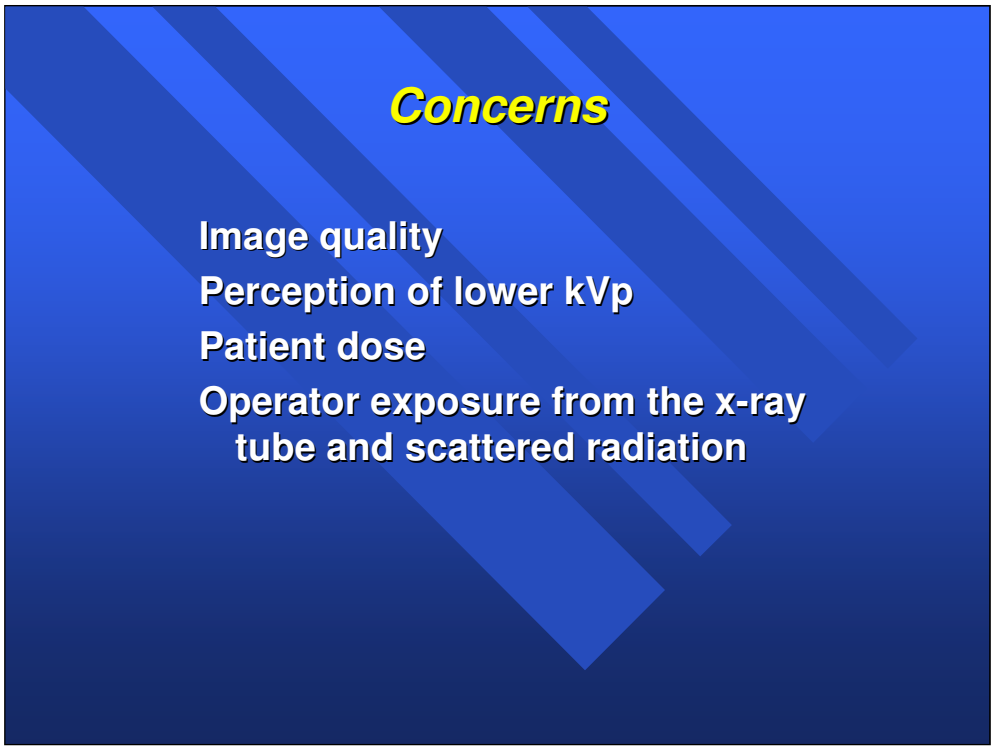
The hand-held, intraoral x-ray system evaluated was the Nomad. For image quality and patient radiation dose purposes this unit was compared to Gendex GX-770 (Gendex Dental Systems, Lake Zurich, Illinois). The specifications for these systems are provided in Slide 8.

The Nomad is specifically designed as a hand-held x-ray device. Consequently, special design features have been incorporated including:

- Increased shielding around the x-ray tube
- Built-in, integral leaded acrylic shield to protect the user from backscattered radiation
- Shielded position indicating device (PID), or collimator.

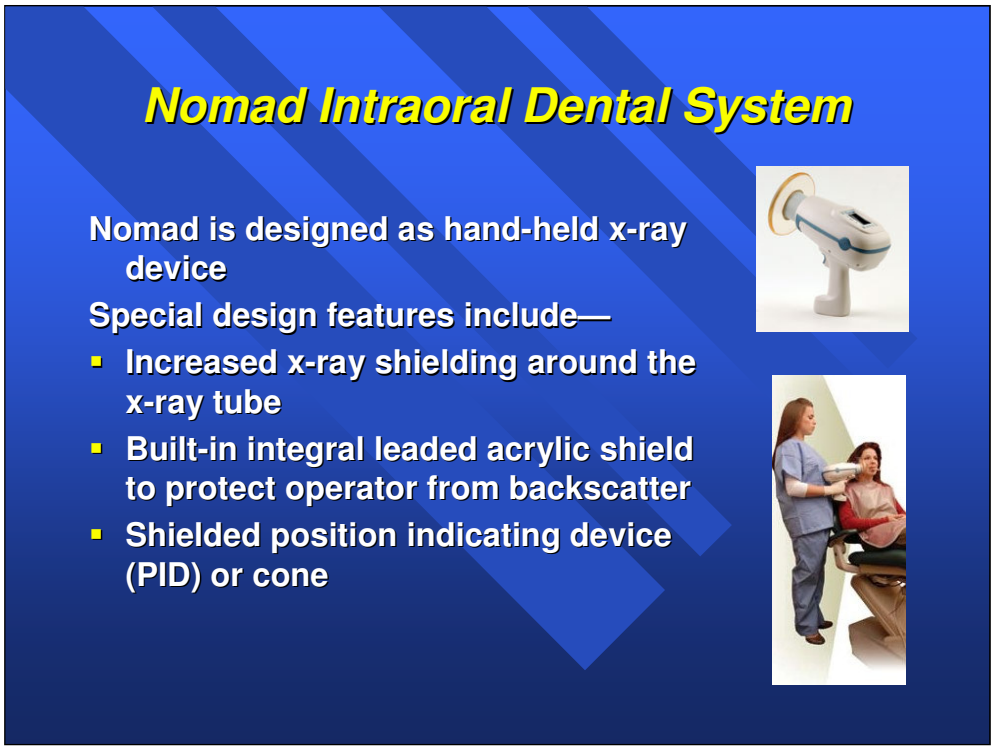
INTRODUCTION

Hand-held, battery-powered x-ray units are coming into use in North America. Over 3,000 units are in use today in the U.S. in dental radiography, veterinary medicine, forensic, military, and research applications.



INTRODUCTION

Regulatory concerns have been expressed about the use of these devices including issues about image quality, patient dose, operator radiation dose from x-ray tube leakage and scatter, and the perception of these units using lower kilovoltage.



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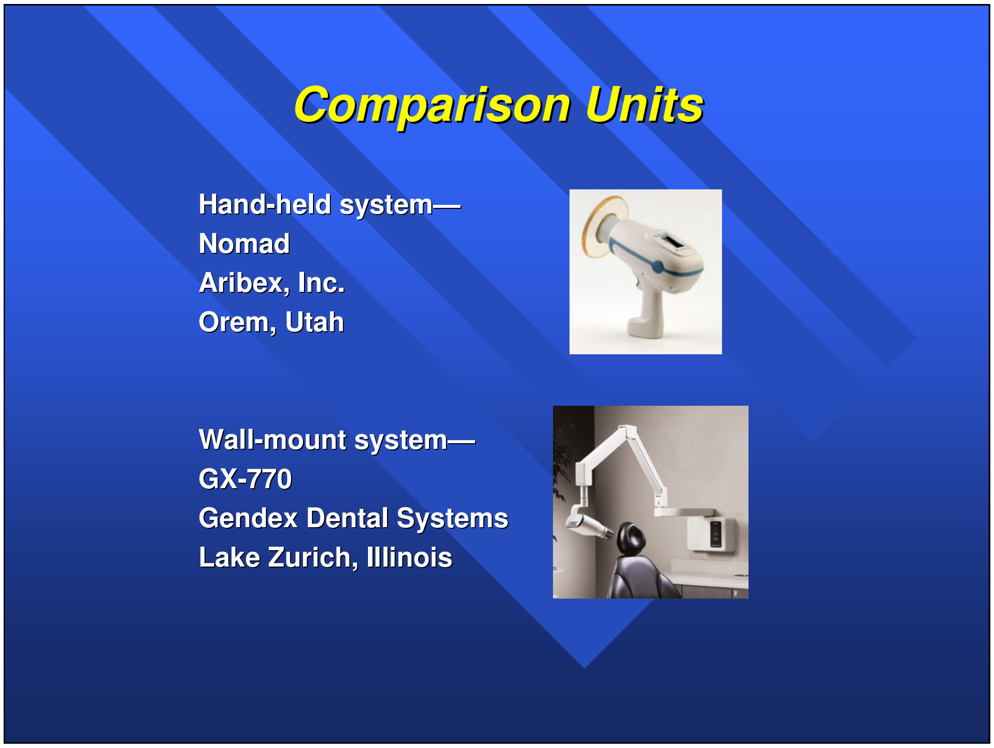


SYSTEMS COMPARED

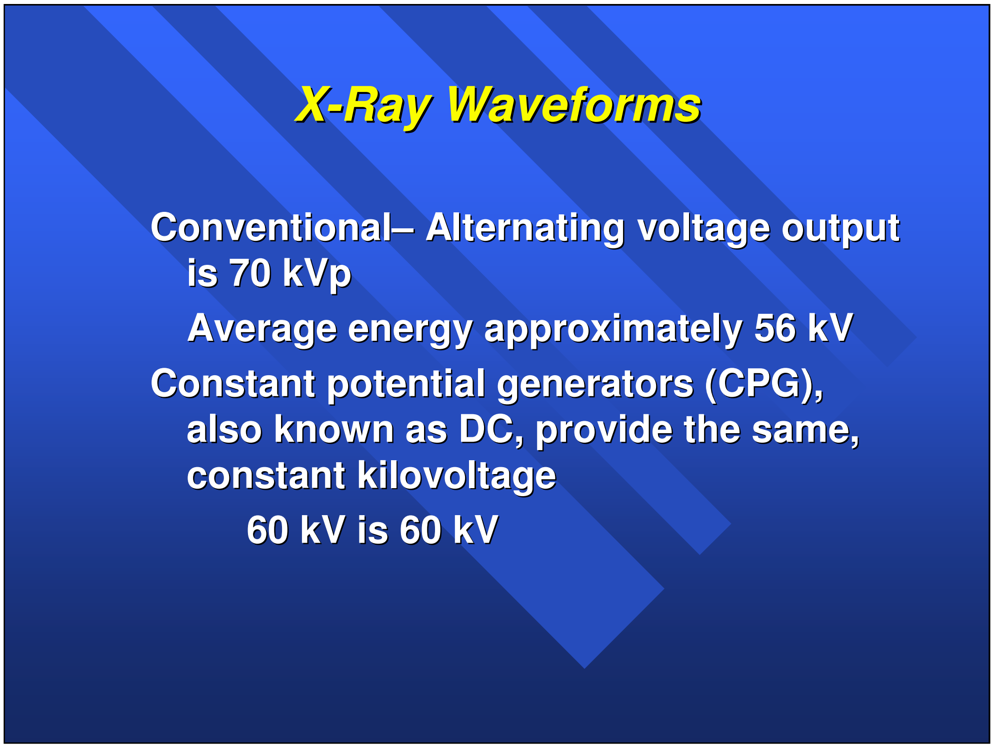
[Continued]

Specifications

	Nomad	Wall-Mount
Kilovoltage	60 (Constant Potential)	70 (Single phase)
mA	2.3	7
Typical exposure time (F-Speed Film) in sec	0.34	0.17
PID diameter (cm)	6	7
Source-to-cone tip (in)	8	8
Focal spot size (mm)	0.4	0.6

SYSTEMS COMPARED

[Continued]



SYSTEMS COMPARED

[Continued]

METHODS

Calculated x-ray waveforms were compared. The kilovoltage waveform for the Nomad was modeled as a constant-potential waveform (Slide 10) with the average kilovoltage being that specified by the manufacturer, i.e., 60 kV. The kilovoltage waveform was modeled as a single-phase waveform for the conventional system (Slide 10) with the peak kilovoltage of 70 kVp. A filter was added to the beam to produce a filtered waveform similar to that found in clinical practice.

Image resolution was measured using a Nuclear Associates 0.025-mm thick lead test pattern (#71412) with frequencies ranging from 1.5 to 20 c/mm. Kodak Insight E-F speed film was used for all images.

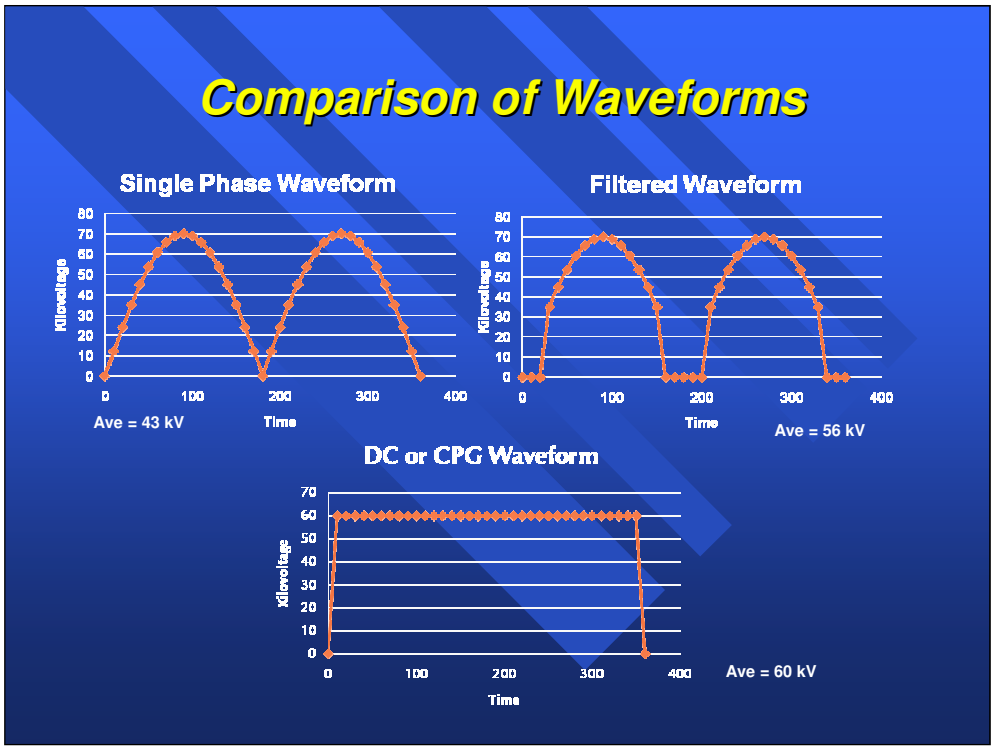
The contrast (density difference) was determined using the FDA dental phantom and measuring the density difference between two areas of the phantom.

The radiation exposure and HVL measurements were made with a Radcal Model 9010 dosimetry system with either a 6 cm3 or 180 cm3 ionization chamber. HVL measurements were made using type 1100 aluminum.

Scattered radiation was measured using a typical one-gallon milk jug filled with water to simulate the human head.

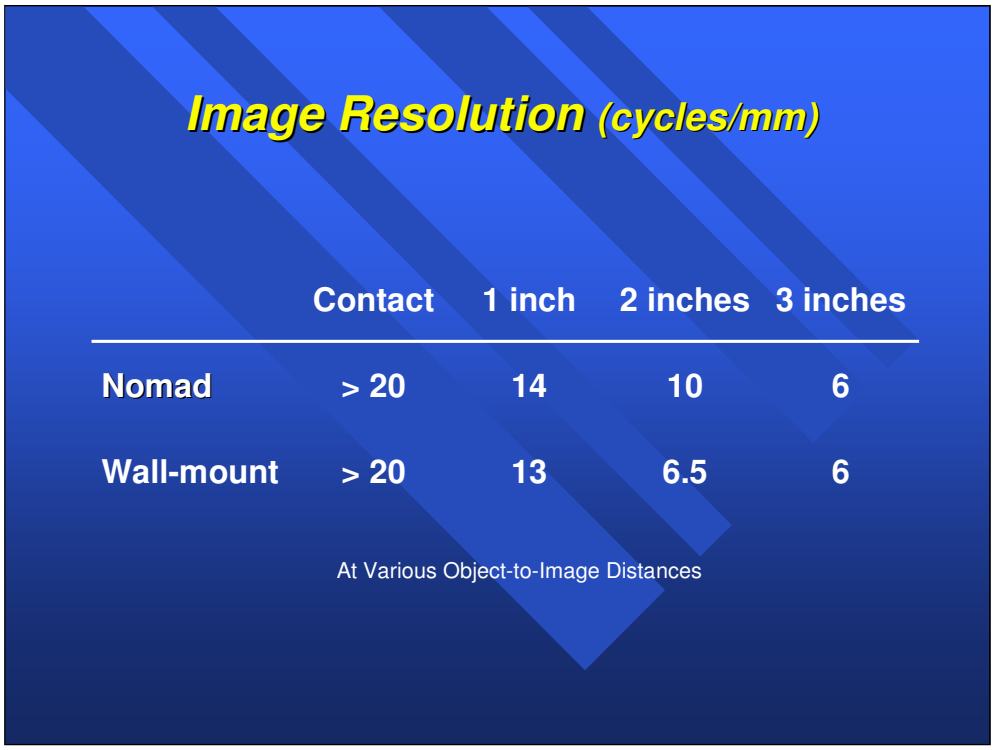
Staff dosimetry measurements were obtained for 18 facilities resulting in 422 reports for Nomad users and 122 reports for users of conventional x-ray equipment for a total of 546 individual staff dosimetry reports. Dose comparisons were carried out in four different ways: a) the percentage of dosimeters showing no measurable radiation; b) the average of all dosimeter readings; c) the average of all non-zero reading dosimeters; and d) the average of paired dosimeter measurements.

"Paired" dosimeter measurements means that staff dosimetry data was obtained from staff using a conventional, wall-mounted system before the introduction of the Nomad. Subsequently staff dosimetry ***from the same operators*** was obtained after the introduction of the Nomad. This resulted in 42 "paired" measurements, i.e., measurements for the same staff using different, conventional intraoral x-ray systems and then the Nomad. The data were from facilities using either D-speed film or digital imaging.



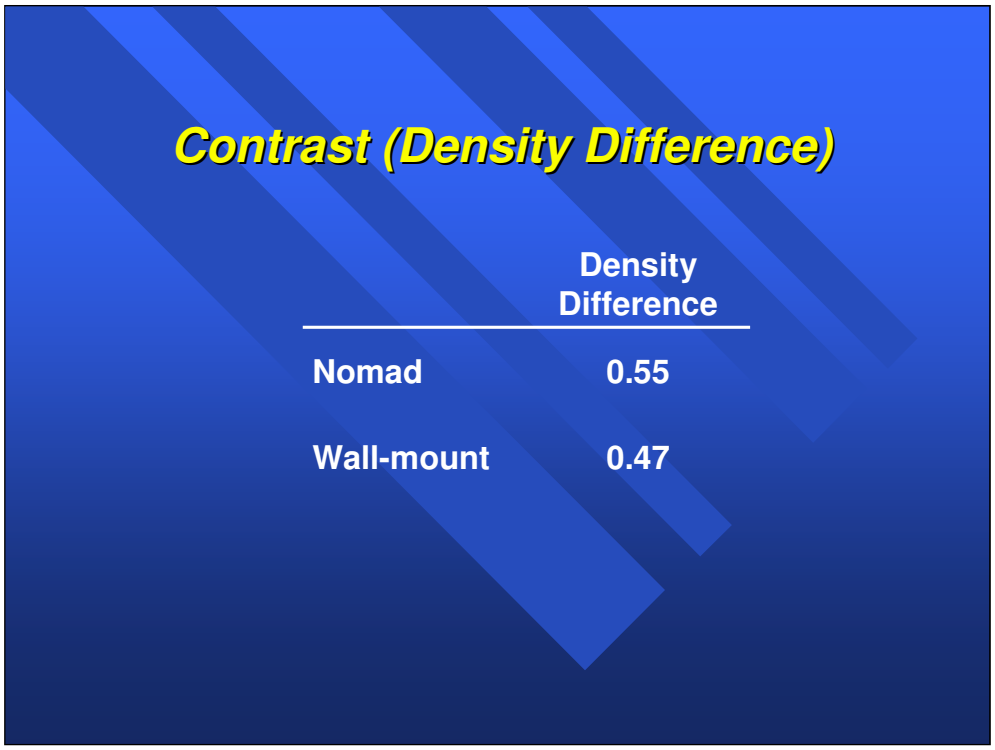
RESULTS

The average kilovoltage for the unfiltered, 70 kVp single phase waveform is 43 kV. With filtration added to meet FDA requirements (1.5 mm HVL at 70 kVp) the average kilovoltage is 56 kV. Consequently, the 60 kV average kilovoltage of the Nomad is higher than that of a filtered 70 kVp beam.



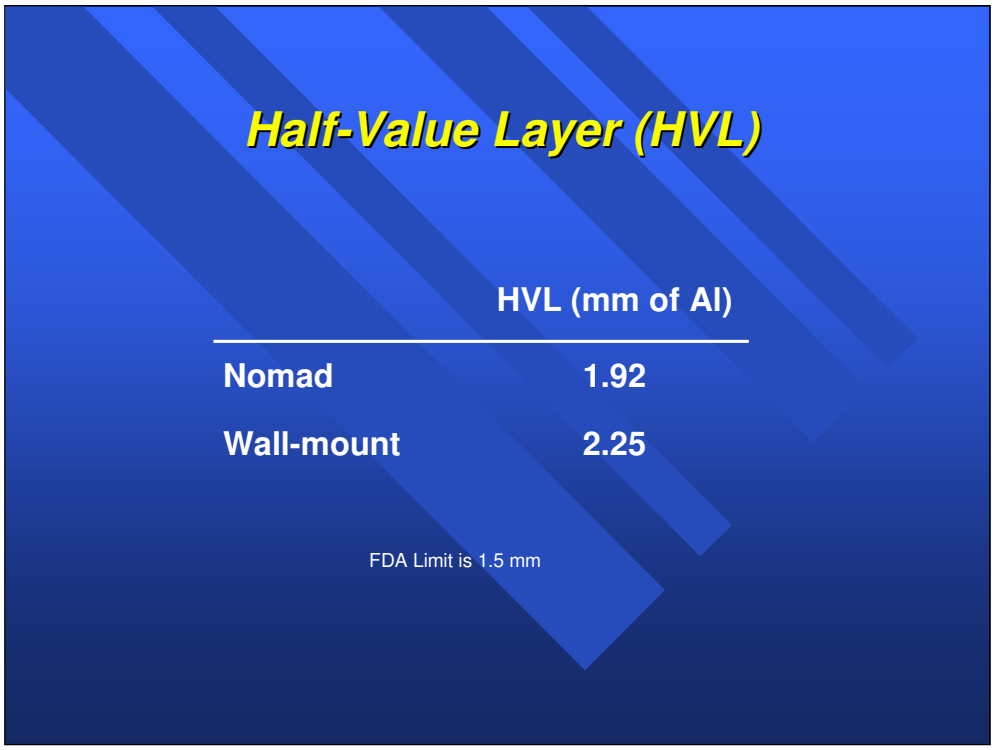
RESULTS

Image resolution is reduced for greater object to image distances, for a fixed focal spot to image distance. In other words, as the object is moved away from the film the resolution is decreased as in clear in Slide 11. When the object, or resolution test pattern, is in contact with the film the resolution is limited by the image receptor (film or digital receptor). The Nomad exhibits better resolution than the conventional system due to the differences in focal spot size (0.4 mm vs 0.6 mm, respectively). It should be noted that the Nomad was hand-held for these exposures, i.e., it was not mounted on a tripod or similar device.



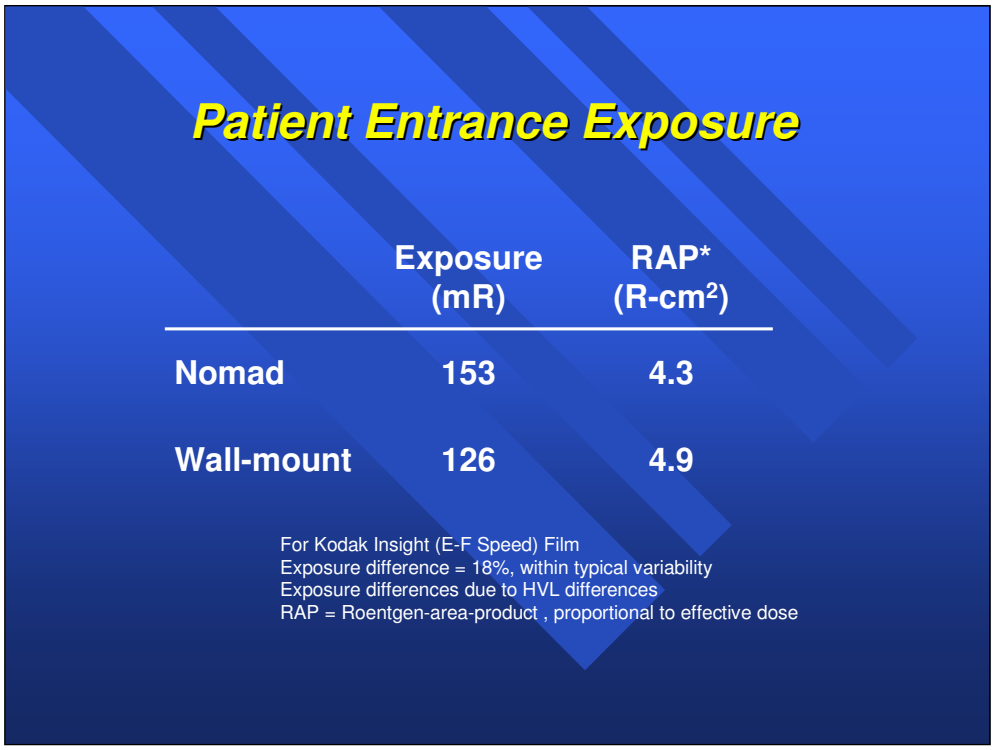
RESULTS

The contrast or density difference was significantly higher (better) for the Nomad as compared to the conventional x-ray system.



RESULTS

The HVLs of the two systems met the FDA minimum values of 1.5 mm Al at 70 kVp, with the conventional x-ray system having a slightly higher HVL.

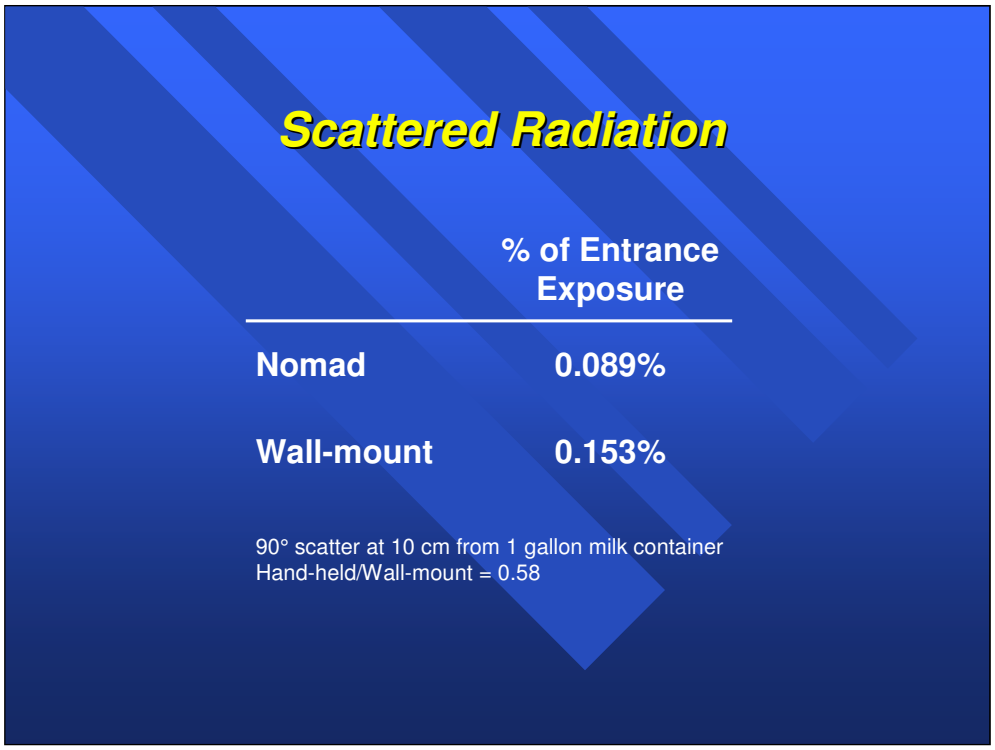


RESULTS

Patient radiation doses were 153 mrad for the Nomad compared to 126 mrad for the conventional system. This 18% difference is well within the variability of patient doses from one unit to another regardless of type of x-ray system. The slightly lower dose for the conventional system is probably due to the slightly higher HVL.

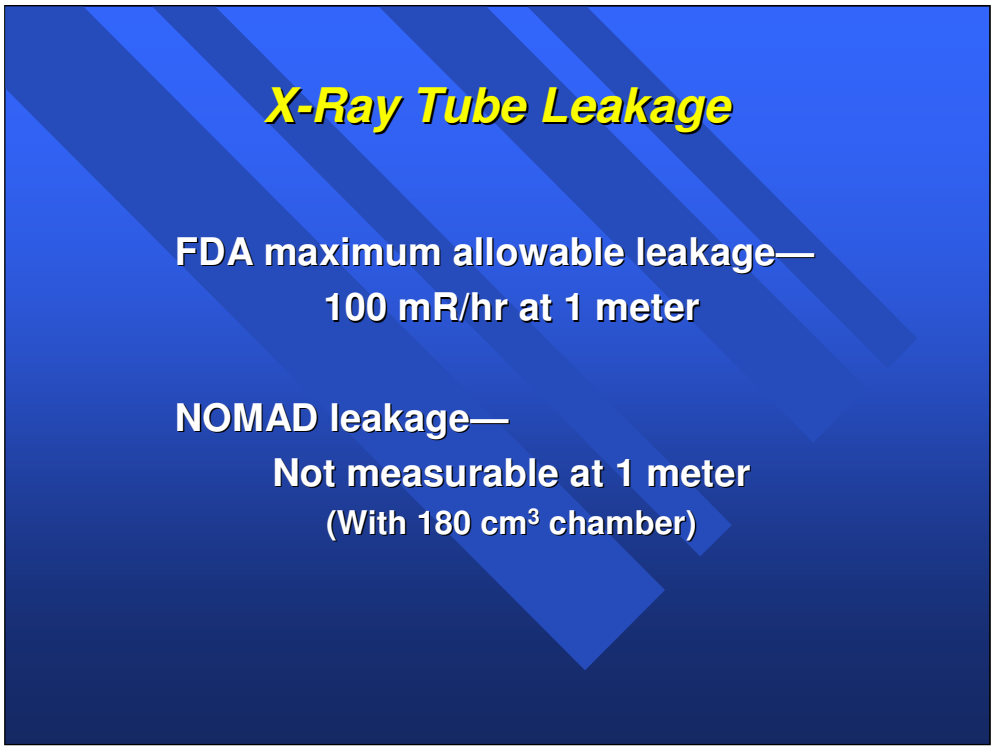
However, it should be stressed that the dose-area product (roentgen-area product, RAP) is lower for the Nomad at 4.3 R-cm2 compared to 4.9 R-cm2 for the conventional system. This indicates that the absorbed radiation dose to the patient for the Nomad will be 14% lower than for the conventional system due to the fact that the irradiated area is smaller for the former compared to

the latter.



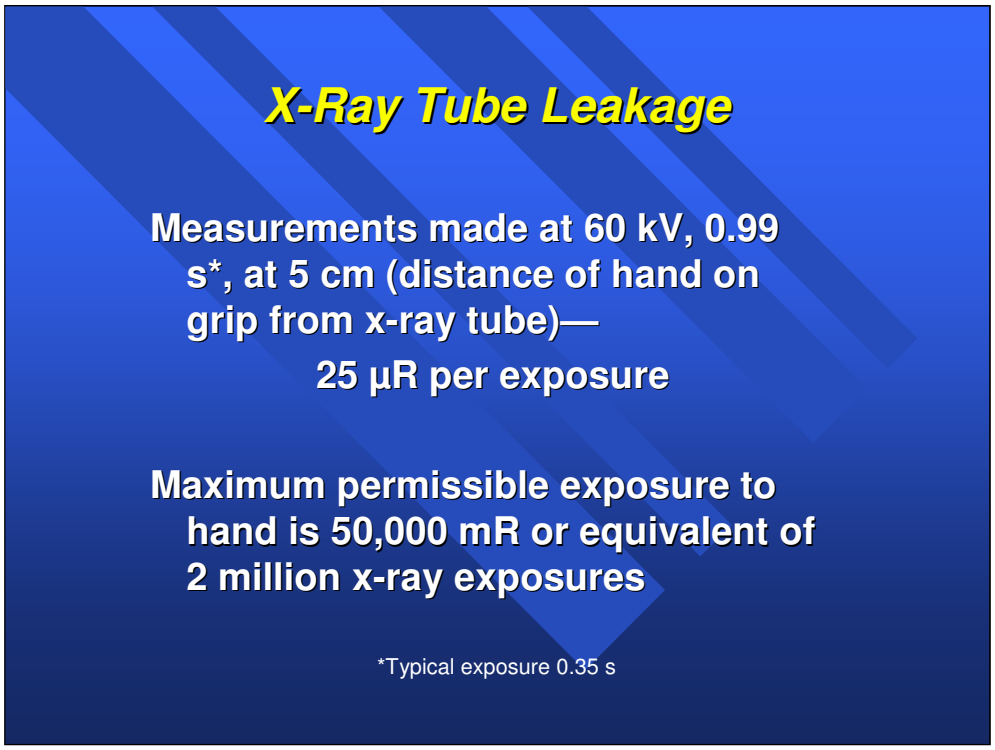
RESULTS

The scattered radiation measured at 90° and 10 cm from the water-filled milk jug was lower for the Nomad at 0.089% of the entrance exposure compared to 0.153% for the conventional system. In other words, the scattered radiation for the Nomad is 58% of that for the conventional system, primarily due to the small irradiated area.



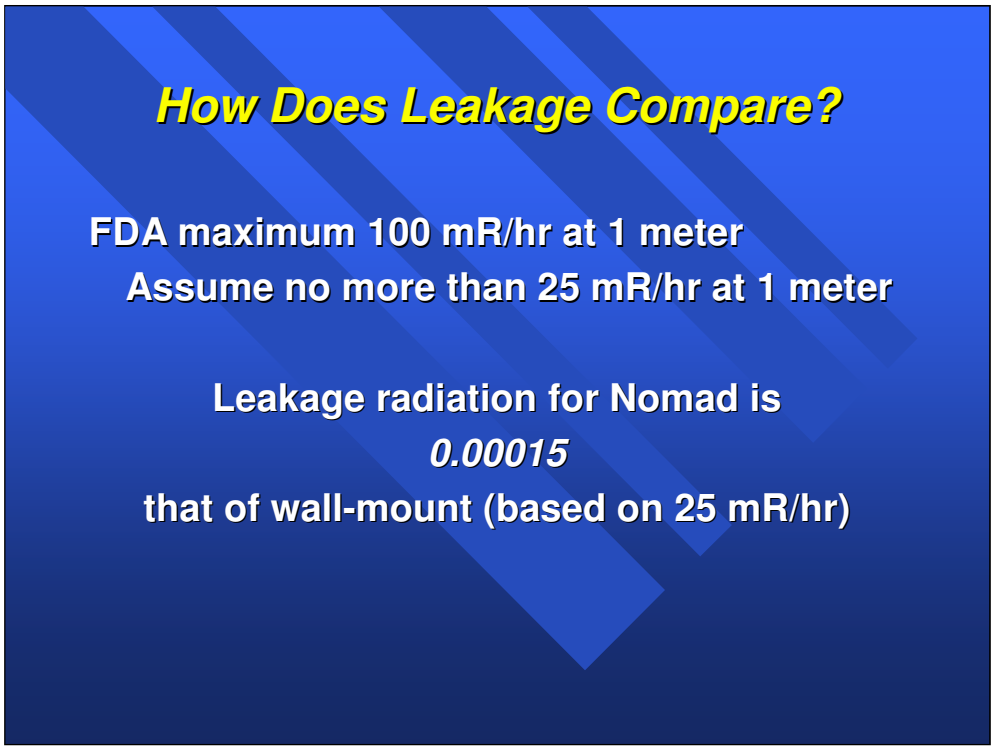
RESULTS

The maximum leakage radiation is specified by the FDA as 100 mR/hr at 1 meter.



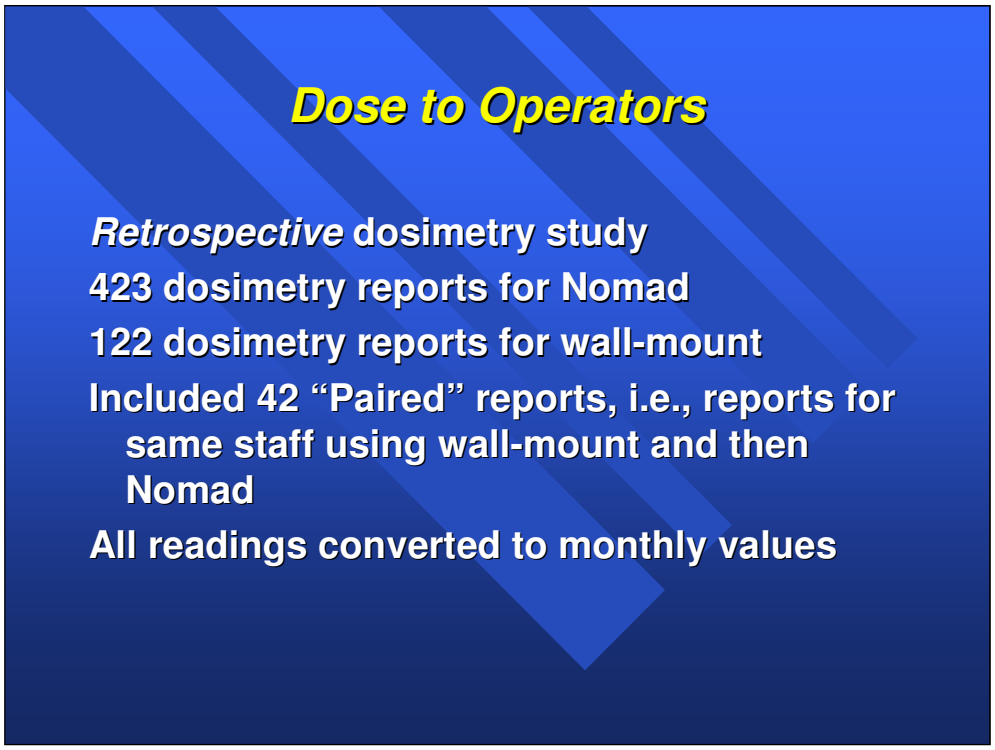
RESULTS

However, most x-ray tube leakage is on the order of 25 mR/hr or less at 1 meter.



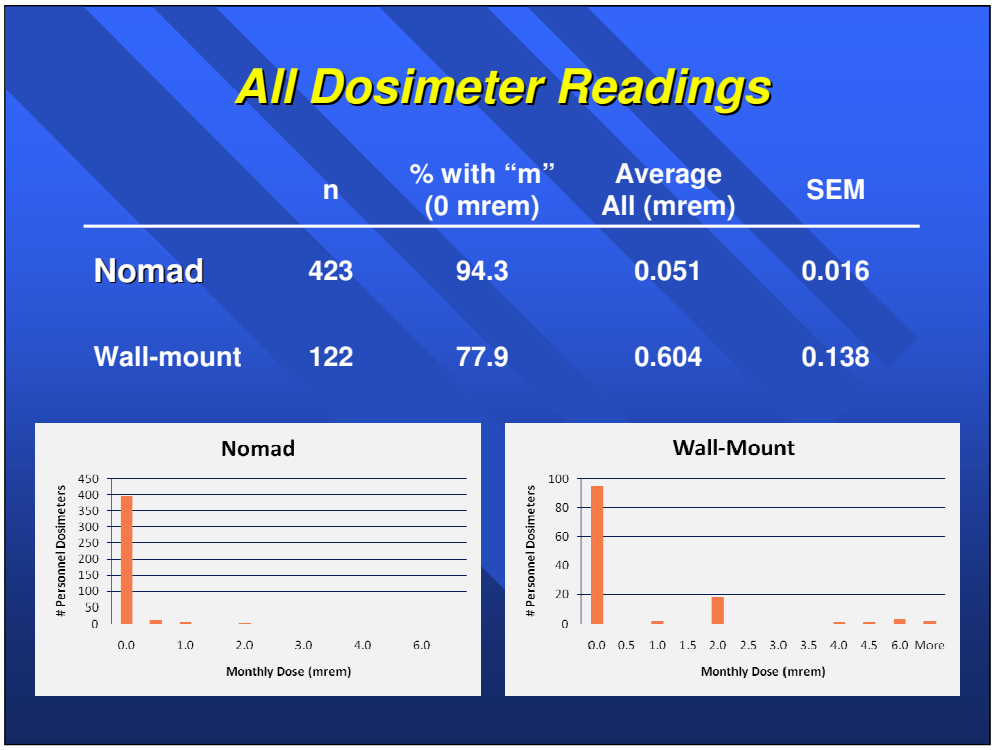
RESULTS

The measured leakage for the Nomad is 0.015% (0.00015) of that for an x-ray tube producing 25 mR/hr.



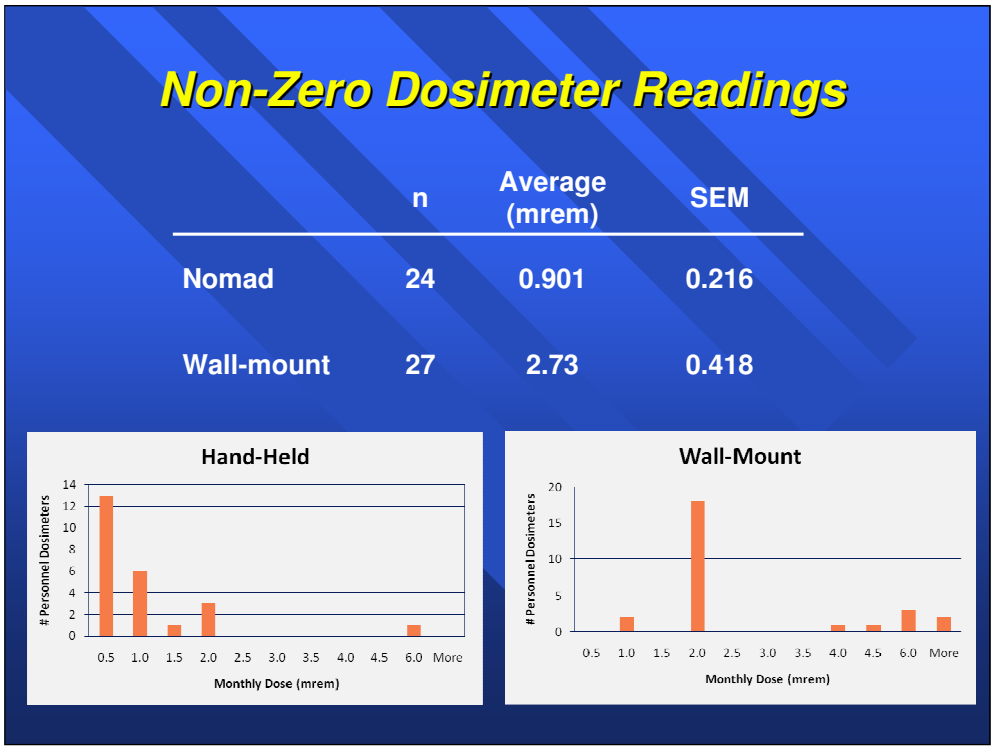
RESULTS

The results of the staff radiation dose measurements are shown in Slides 20-22. The percentage of dosimeters showing no measurable radiation (M, or 0 mrem) for Nomad users was 94.3% while that for the users of conventional x-ray systems was 77.9%.



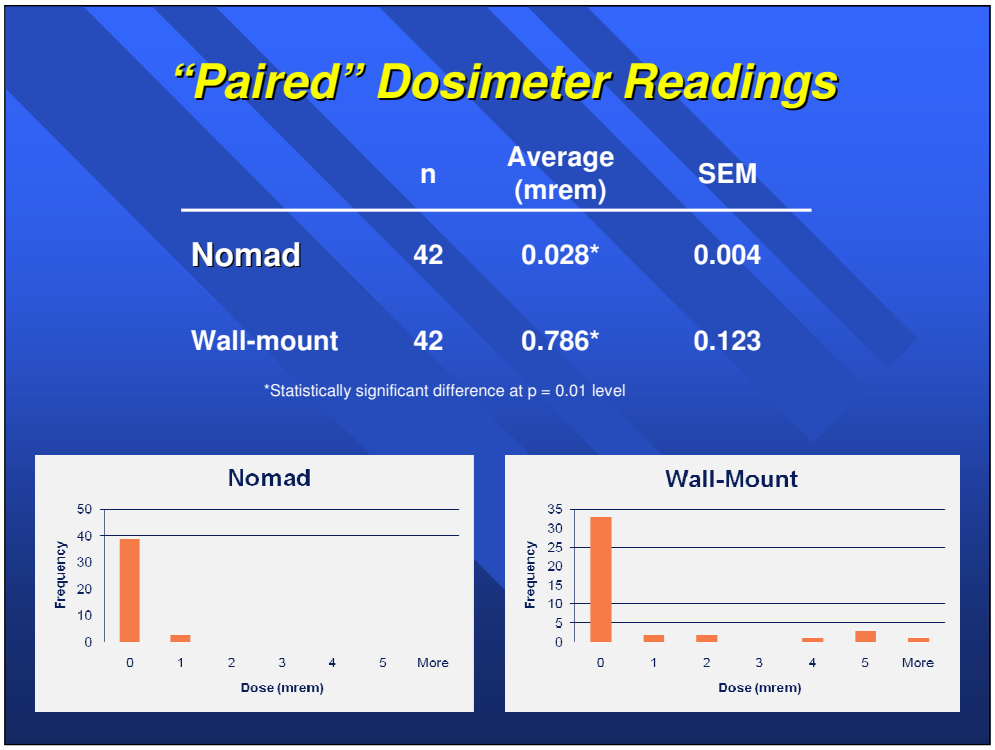
RESULTS

The average monthly dose for all dosimeters from Nomad users was 0.051 mrem and 0.604 for users of conventional equipment. In other words, Nomad users received about 8% of the radiation dose received by users of conventional equipment.



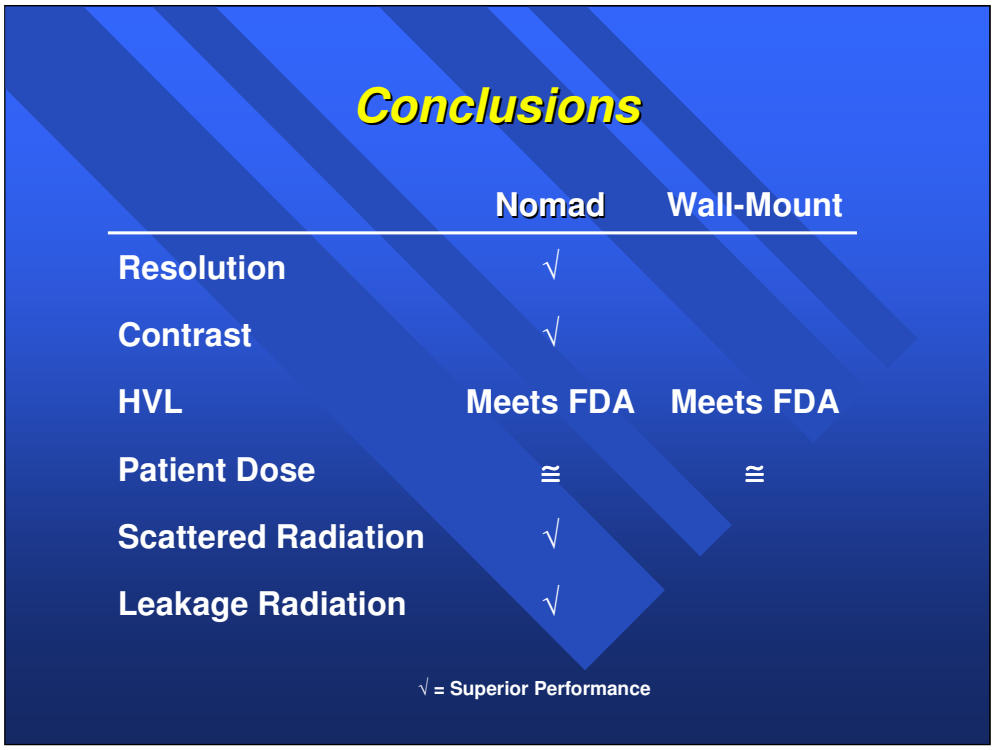
RESULTS

The average staff dose for those with the non-zero dosimeter readings was 0.901 mrem for the Nomad compared to 2.73 mrem for users of conventional intraoral x-ray systems. In this case, the average staff dose for Nomad users was 33% of that for users of conventional equipment.



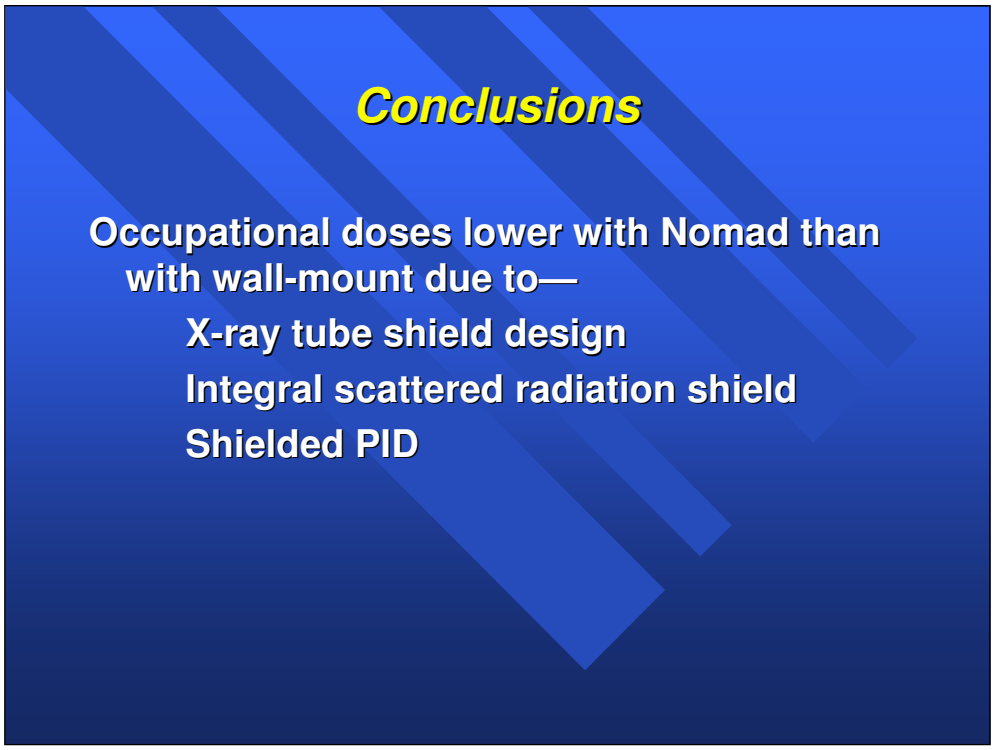
RESULTS

The comparison of staff dosimetry for "paired" measurements removes many of the variables, e.g., work load, etc., from the data. The average monthly, paired staff doses for the Nomad users was 0.028 mrem compared to 0.786 mrem for those using conventional intraoral x-ray systems, a statistically significant difference at the p = 0.01 level. In other words, the average monthly dose for the Nomad users was 3.6% of that for users of conventional dental x-ray systems.



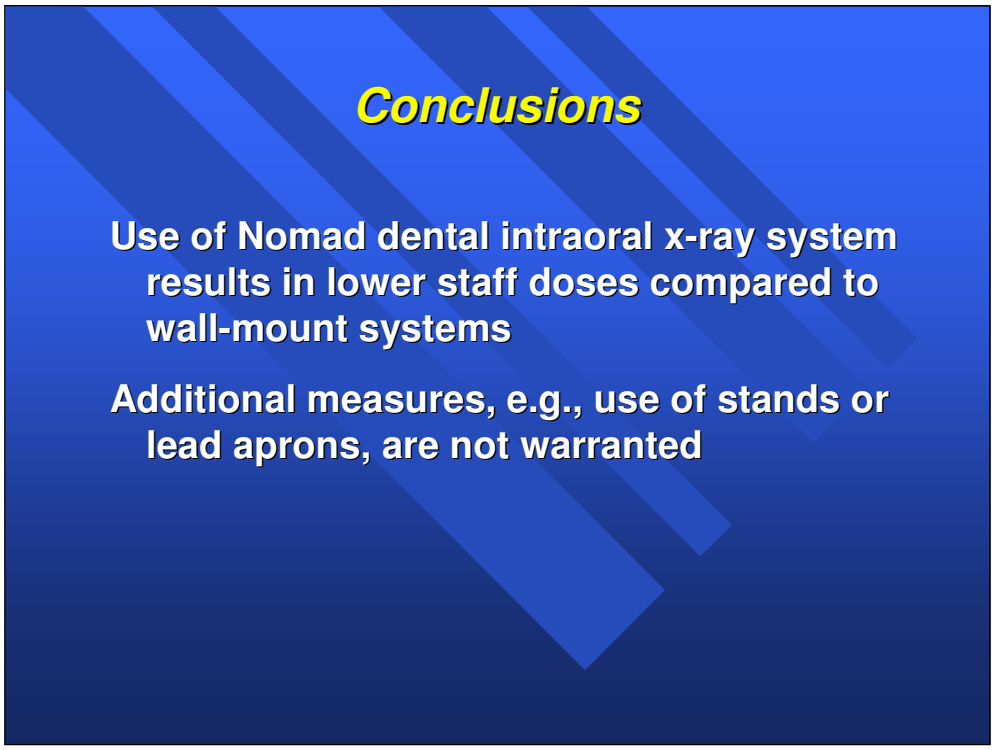
CONCLUSIONS

In conclusion, this study indicates that the resolution and contrast for the Nomad are superior to the Gendex x-ray system. In addition, the leakage and scattered radiation are lower for the Nomad compared to conventional, wall-mounted intraoral dental systems. The HVL meets the FDA requirements, with the Gendex having a slightly higher HVL than the Nomad. Both entrance radiation doses and the dose-area products for the two systems are similar.



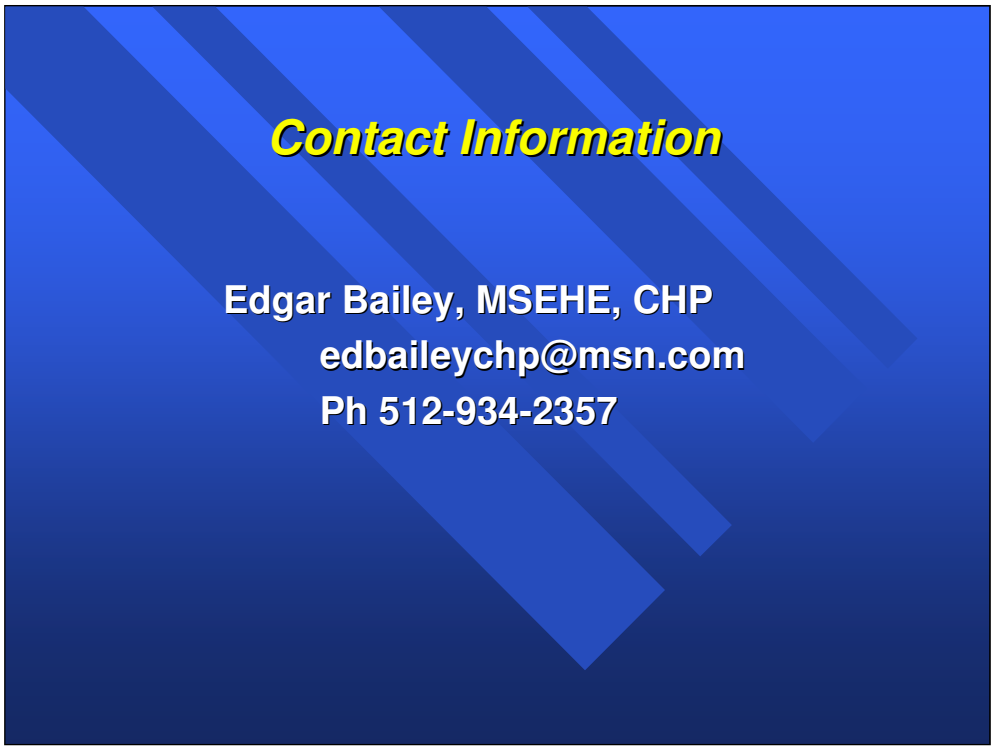
CONCLUSIONS

Occupational doses are lower with the Nomad than with conventional intraoral x-ray systems. This is probably due to the tube shielding design (the Nomad is designed to be hand held and has significantly more shielding around the x-ray tube than a conventional system), the Nomad integral shield to protect the user from scattered radiation, and the shielded position indicating device collimator).



CONCLUSIONS

Based on the results of this study, use of the Nomad dental intraoral x-ray system results in significantly lower staff doses compared to wall-mounted systems. Consequently, additional measures, e.g., use of lead aprons or stands, are not warranted.



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