

# ***Image Quality and Radiation Dose for Intraoral Radiography: Hand-Held (Nomad), Battery Powered vs. Wall-Mount X-Ray Systems***

**Edgar Bailey\***, MSEHE, CHP

Consultant

**Joel Gray\***, PhD, FAAPM

DIQUAD, LLC

**John Ludlow, DDS**

School of Dentistry, University of North Carolina

\*Consultant to Aribex, Inc., Orem, Utah

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## **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.

## ***Apologies***

**Our apologies for using the brand name of a commercial product so frequently**

**At 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**

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.

## ***Purpose***

**Compare Nomad intraoral x-ray systems to wall-mount systems in terms of—**

**Image resolution**

**Contrast**

**Half Value Level (HVL)**

**Patient dose**

**Scattered radiation**

**X-ray tube leakage**

**Dose to operators**

## **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.

## ***Background***

- Hand-held units are coming into use in North America
- Several firms are manufacturing hand-held overseas and beginning to market these in the U.S.A.
- Over **3000** units are in use today in the U.S. in dental radiography, veterinary medicine, forensic, military, and research applications
- Regulatory concerns have been expressed about these devices

### **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.

## ***Concerns***

**Image quality**

**Perception of lower kVp**

**Patient dose**

**Operator exposure from the x-ray  
tube and scattered radiation**

### **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.

## ***Nomad Intraoral Dental System***

Nomad is designed as hand-held x-ray device

Special design features include—

- Increased x-ray shielding around the x-ray tube
- Built-in integral leaded acrylic shield to protect operator from backscatter
- Shielded position indicating device (PID) or cone



### **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
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## ***Comparison Units***

Hand-held system—  
Nomad  
Aribex, Inc.  
Orem, Utah



Wall-mount system—  
GX-770  
Gendex Dental Systems  
Lake Zurich, Illinois



### **SYSTEMS COMPARED**

[Continued]

## ***Specifications***

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

### **SYSTEMS COMPARED**

[Continued]



## ***X-Ray Waveforms***

**Conventional– Alternating voltage output  
is 70 kVp**

**Average energy approximately 56 kV**

**Constant potential generators (CPG),  
also known as DC, provide the same,  
constant kilovoltage**

**60 kV is 60 kV**

### **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.

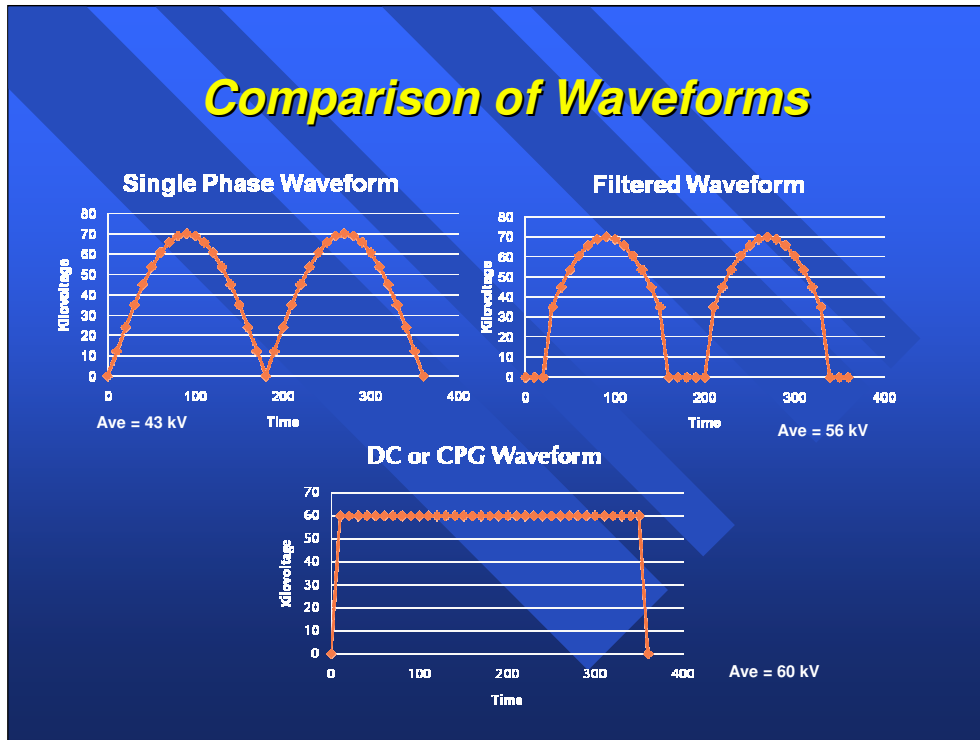
The radiation exposure and HVL measurements were made with a Radcal Model 9010 dosimetry system with either a 6 cm<sup>3</sup> or 180 cm<sup>3</sup> ionization chamber. HVL measurements were made using type 1100 aluminum.

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.

## Comparison of Waveforms



### 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.

***Image Resolution (cycles/mm)***

	Contact	1 inch	2 inches	3 inches
<b>Nomad</b>	> 20	14	10	6
<b>Wall-mount</b>	> 20	13	6.5	6

At Various Object-to-Image Distances

**RESULTS**

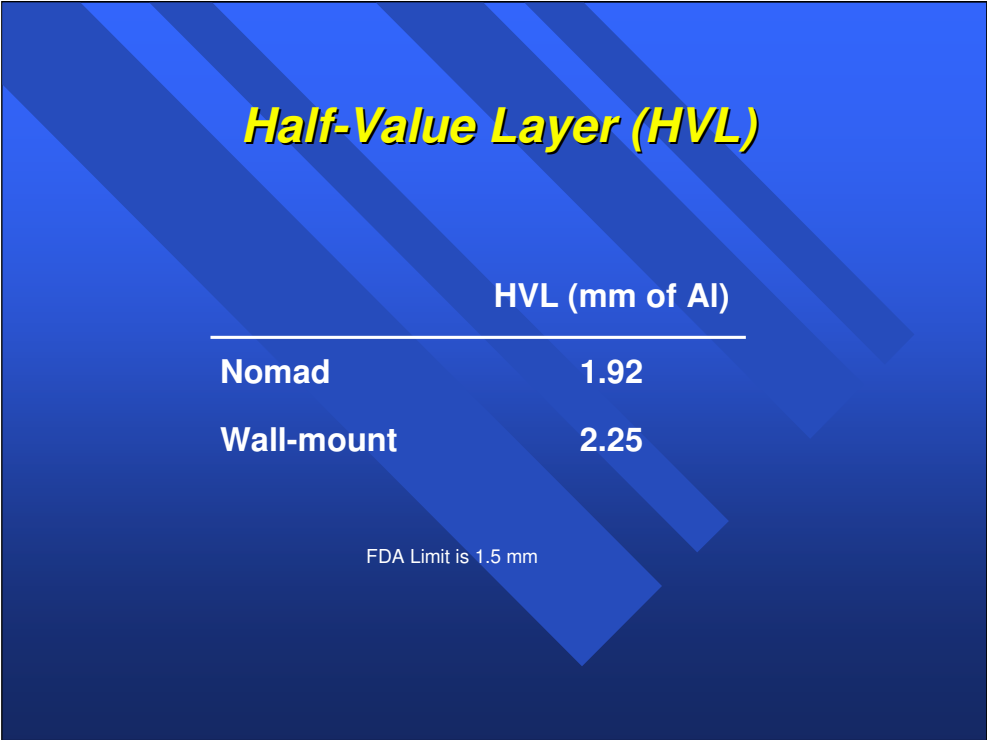
Image resolution is reduced for greater object to image distances, for a fixed focal spot to image distance. In other words, as the object is moved away from the film the resolution is decreased as in clear in Slide 11. When the object, or resolution test pattern, is in contact with the film the resolution 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.

## ***Contrast (Density Difference)***

	Density Difference
Nomad	0.55
Wall-mount	0.47

### **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.

## ***Patient Entrance Exposure***

	<b>Exposure (mR)</b>	<b>RAP* (R-cm<sup>2</sup>)</b>
<b>Nomad</b>	<b>153</b>	<b>4.3</b>
<b>Wall-mount</b>	<b>126</b>	<b>4.9</b>

For Kodak Insight (E-F Speed) Film  
Exposure difference = 18%, within typical variability  
Exposure differences due to HVL differences  
RAP = Roentgen-area-product, proportional to effective dose

### **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-cm<sup>2</sup> compared to 4.9 R-cm<sup>2</sup> 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.

## ***Scattered Radiation***

	<b>% of Entrance Exposure</b>
<b>Nomad</b>	<b>0.089%</b>
<b>Wall-mount</b>	<b>0.153%</b>

90° scatter at 10 cm from 1 gallon milk container  
Hand-held/Wall-mount = 0.58

### **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.

## ***X-Ray Tube Leakage***

**FDA maximum allowable leakage—  
100 mR/hr at 1 meter**

**NOMAD leakage—  
Not measurable at 1 meter  
(With 180 cm<sup>3</sup> chamber)**

### **RESULTS**

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



## ***X-Ray Tube Leakage***

Measurements made at 60 kV, 0.99 s\*, at 5 cm (distance of hand on grip from x-ray tube)—  
25  $\mu$ R per exposure

Maximum permissible exposure to hand is 50,000 mR or equivalent of 2 million x-ray exposures

\*Typical exposure 0.35 s

### **RESULTS**

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

## ***How Does Leakage Compare?***

FDA maximum 100 mR/hr at 1 meter

Assume no more than 25 mR/hr at 1 meter

Leakage radiation for Nomad is

*0.00015*

that of wall-mount (based on 25 mR/hr)

### **RESULTS**

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

## ***Dose to Operators***

***Retrospective dosimetry study***

**423 dosimetry reports for Nomad**

**122 dosimetry reports for wall-mount**

**Included 42 “Paired” reports, i.e., reports for same staff using wall-mount and then Nomad**

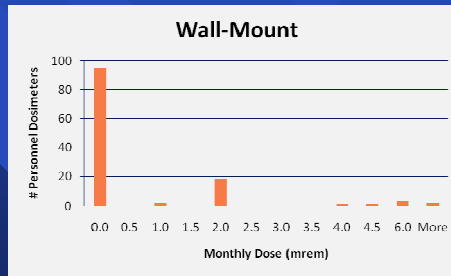
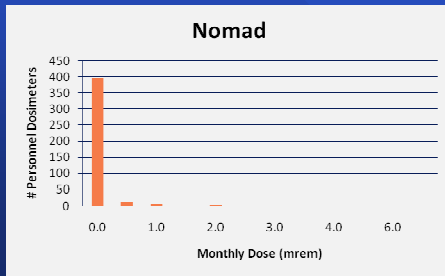
**All readings converted to monthly values**

### **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%.

## *All Dosimeter Readings*

	n	% with "m" (0 mrem)	Average All (mrem)	SEM
Nomad	423	94.3	0.051	0.016
Wall-mount	122	77.9	0.604	0.138

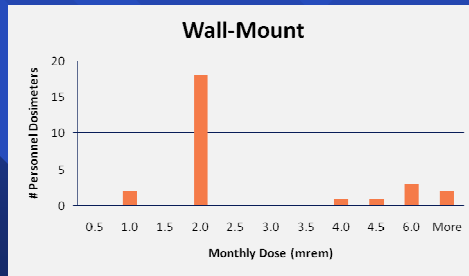
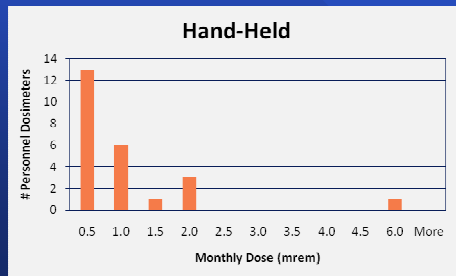


### RESULTS

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.

## Non-Zero Dosimeter Readings

	n	Average (mrem)	SEM
Nomad	24	0.901	0.216
Wall-mount	27	2.73	0.418



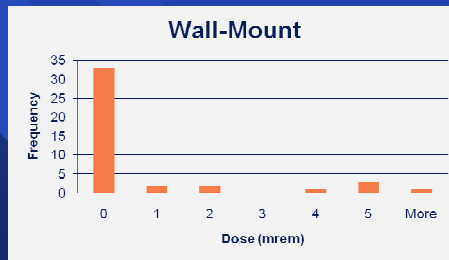
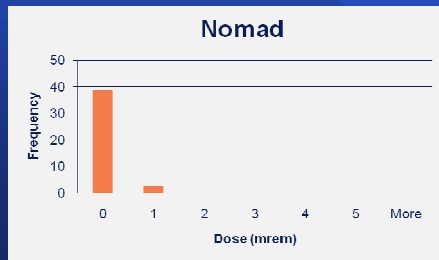
## RESULTS

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.

## ***“Paired” Dosimeter Readings***

	n	Average (mrem)	SEM
Nomad	42	0.028*	0.004
Wall-mount	42	0.786*	0.123

\*Statistically significant difference at  $p = 0.01$  level



## **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

	Nomad	Wall-Mount
Resolution	√	
Contrast	√	
HVL	Meets FDA	Meets FDA
Patient Dose	≅	≅
Scattered Radiation	√	
Leakage Radiation	√	

√ = Superior Performance

### 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 lower with Nomad than  
with wall-mount due to—**

**X-ray tube shield design**

**Integral scattered radiation shield**

**Shielded PID**

### **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***

**Use of Nomad dental intraoral x-ray system results in lower staff doses compared to wall-mount systems**

**Additional measures, e.g., use of stands or lead aprons, are not warranted**

### **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.

## **Contact Information**

**Edgar Bailey, MSEHE, CHP**  
**edbaileychp@msn.com**  
**Ph 512-934-2357**

Edgar Bailey, M.S.E.H.E., C.H.P.  
2804 Misty Shore Lane  
Pflugerville, Texas 78660-7744  
e-mail edbaileychp@msn.com

Joel Gray, Ph.D.  
DIQUAD, LLC  
222 Lakeview Court  
Steger, Illinois 60475

John Ludlow, D.D.S.  
School of Dentistry  
University of North Carolina  
Chapel Hill, North Carolina 27599