PROFESSIONAL PAPER (STRUČNI RAD)

# The utilization of a handheld X-ray device for intraoral imaging in modern dental practice

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## Abstract

Recently, there has been an increased interest in the utilization of a handheld X-ray devices for intraoral imaging in modern dental practice. Globally, several documents with recommended guidelines on the utilization of a handheld X-ray device for intraoral imaging have been issued. Considering that the recommended guidelines were contradictory, additional research was initiated on the justification of manual utilization in everyday practice. The goal of this article is to present the justification for the utilization of a handheld X-ray devices as an alternative to wall mounted fixed devices that has been presented by several studies that examined the level of radiation received by the operator, the environment and the patient. In the interest of research, the emphasis was also on the radiological image quality control. Although the results of the quality parameters on the radiological image with both types of devices proved to be successful, the results of the radiation dose oscillated and were not completely acceptable for the operator, the environment and the patient, if all radiation protection guidelines were not followed. Further research should be done additionally on people, instead on models and phantoms, before they are fully introduced into everyday dental practice.

**Keywords**: handheld; NOMAD; Heliodent; intraoral; dentistry; radiography

## Introduction

In modern dental practice, the utilization of radiological images improves diagnostic and therapeutic quality and dental radiography is still one of the most frequently performed radiological procedures in the world [1]. Relatively recent changes in laws governing dental practice worldwide, increased interest in the utilization of handheld X-ray portable intraoral imaging devices in daily practice, resulting with contradictory recommended guidelines for the utilization of a handheld device [2]. In 2015, the working group of the EADMFR (European Academy of Dento-Maxillofacial Radiology) issued recommendations on the utilization of a handheld device when treating patient teeth under general anesthesia or sedation, in nursing homes or institutions for patients with special needs, prisons or underdeveloped regions that lack dental facilities, with the prohibition of utilization for routine radiographic procedures in dental offices. ADA (American Dental Association), in 2019 issued guidelines, placed no restrictions on the utilization of a handheld devices and provided that all specified precautions were taken regarding device utilization and storing. The NCRP (National Council for Radiation Protection and Measurements), in its publication on radiation protection in oral and maxillofacial radiology from 2019, considered that the guidelines of the working group of the EADMFR were too restrictive and that handheld devices can be used in children or endodontic procedures [2].

Every legal entity, which has responsibility under national law for a radiological establishment, must organize quality assurance procedures for actions involving radiation exposure and the control quality assurance program. Among control quality assurance activities, operators should perform an analysis of rejected images to verify that rejection rates do not exceed the usual control quality standard for intraoral radiography. Companies that distribute handheld portable devices are responsible for dissemination of information and educating professionals about radiation protection measures for the operator, the environment, and the patients [3].

## Dental radiographic devices for intraoral imaging

### Wall mounted device

Typical and standard method of teeth intraoral imaging in everyday practice is performed with a wall mounted fixed device that is attached to a "positioning arm" with a high-voltage cable for connecting the X-ray tube (60-70 kV) and the high-voltage generator. The device is wall mounted and is therefore limited in mobility (Figure 1). Imaging with the device is enabled by selecting settings on the device control panel and by manipulating the "positioning arm" towards the digital image receptor, inside the patient's mouth (Figure 2) [1,2].


**Figure 1.** A) The example of wall mounted X-ray device
*Source:* https://pocketdentistry.com/3-dental-x-ray-equipment-image-receptors-and-image-processing/


**Figure 2.** A,B,C) Different control panels of wall mounted X-ray device by several manufacturers
*Source:* https://pocketdentistry.com/3-dental-x-ray-equipment-image-receptors-and-image-processing/

### Handheld X-ray device

Recently, an alternative to the wall mounted device has appeared, in the form of a handheld portable device whose feature is convenient size and easy handling and at the same time offers equivalent radiation doses for the operator as well as the wall mounted device (Figure 3) [1,2]. The handheld portable device is built on the

**Figure 3.** The utilization of handheld X-ray device in practice
*Source:* http://lionsdentalsupply.com/Nomad-Pro-2-Handheld-X-Ray-Unit.html

principle of a photographic camera and looks like a shotgun [4]. The X-ray generator use batteries with wireless mode and is not fixed, but is held by the operator during the imaging. Nickel-cadmium rechargeable batteries are usually at 14.4 V and with one charge (approximately 8 hours) provide 100-700 exposures. On the inside of the X-ray tube is a lead shield, and a lead-acrylic shield on the outside with an automatic selection of reducing the risk of accidental exposure [4]. The shields must be transparent with an equivalent lead thickness of 0.25 mm [2]. The handheld device has na electric current flowing, operates at a fixed 60 kV, 2.3 mA and has a focal spot of 0.4 mm with a distance from the X-ray source to the skin of 20 cm [4]. In modern practice, the NOMAD™ Pro 2 device is mostly used (Figure 4).

**Figure 4.** NOMAD™ Pro 2 X-ray handheld device
*Source:* http://lionsdentalsupply.com/Nomad-Pro-2-Handheld-X-Ray-Unit.html

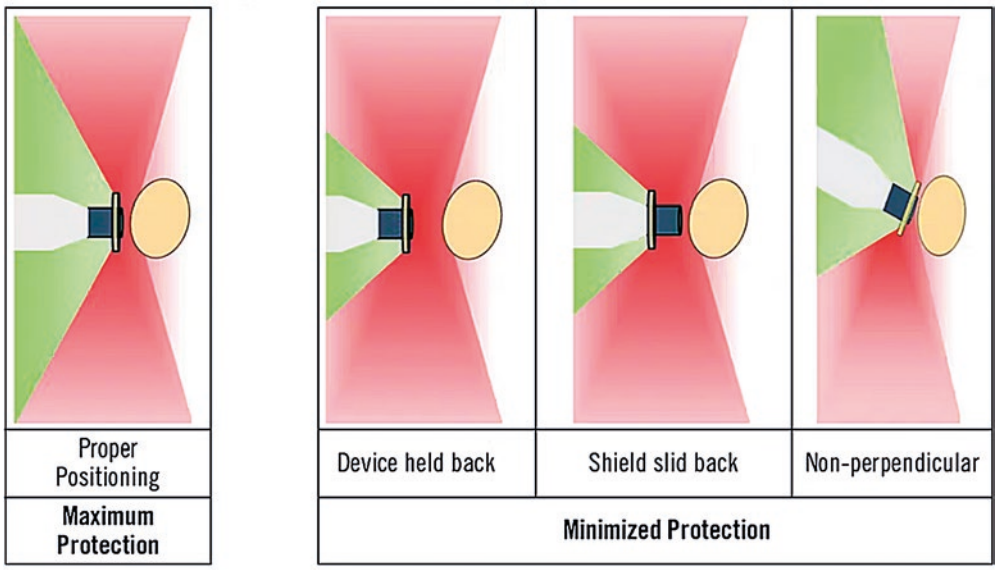


**Figure 5.** Demonstration of achieving the maximum and minimum level of radiation protection using a handheld device
*Source:* https://www.rdhmag.com/patient-care/article/14068492/handheld-vs-conventional-wall mounted-x-ray-units

Although handheld device has advantages such as portability and lower costs there are also some disadvantages. Lack of the battery power can result in inconsistent output radiation, which affects in reduced quality of the images [5]. The greatest challenge is the position of the operator, who needs to be within the protective zone from scattered radiation to avoid unnecessary long-term exposure to X-rays during work. For maximum protection, the handheld device should be perpendicular to the image receptor so the X-ray is in a horizontal plane. Minimal protection is achieved if the device is far from the zone of interest, if the lead shield is not placed correctly and if the device is not perpendicular to the image receptor (Figure 5). The disadvantages like the fatigue of the operator due to the certain difficulty of using the handheld device and the lack of manipulation with free hands can affect the quality of the obtained image [5]. If the handheld device is used in an open area, a controlled perimeter must be established. The controlled perimeter ensures that the dental staff does not stand in the way of the X-ray beam, does not remain behind a protective barrier or stands at least 1.8 meters from the patient and between 90°-135° due to the direction of the primary beam during exposure [5].

## Discussion

Several studies have been focused on the justification of the conflicted guidelines in the laws which have stimulated a discussion about the challenges that need to be investigated when using a handheld device in daily practice. Those are: the level of radiation dose for the operator, the environment and the patient, and the radiographic imaging quality control [2].

### Radiation dose level for the operator, the environment and the patient

The presence of an external lead-acrylic shield as the only physical barrier between the operator and backscattered radiation from the patient, as well as holding the generator of the device directly in the hands, led to polemics about the operator and the environment protection [2].

Rottke et al., examined, among other things, operator safety during acquisition, i.e. radiation protection and dose values when taking intraoral images, with the help of the Aribex NOMAD Pro 2 handheld device, referring to the German "Regulation on protection against risks arising from X-rays ". The measurement results showed that the device is convenient for utilization and that the operator is not exposed to X-ray leakage or scattered radiation if he is behind the plane of the focal spot. The received dose of scattered radiation depends on the angle of inclination of the tube and on the distance of the imaging object from the X-ray source. No scattered radiation was detected dorsally and above the phantom because the relatively soft radiation, which came from the 60 kV tube, could not penetrate through the bony parts of the phantom, but small dose values were detected below the phantom's chin, which emphasizes the mandatory use of protective devices on the thyroid gland [6]. It is necessary to train staff about correct device handling in order to reduce the risk of radiation and use it in accordance with the manufacturer's instructions [2,6].

According to Patel et al., the radiation dose received by the patient is 50% lower if a rectangular collimator is used [7]. Otaka et al., studied the effect of radiation dose reduction on operator professional exposure and public exposure when using a backscatter shield and a rectangular collimator on the device during manual utilization of the device. Placing a protective shield on the X-ray cone peak was shown to be effective in reducing the operator professional exposure to 40%, to 13% when a rectangular collimator was attached, and to 7.7% when the backscatter shield and rectangular collimator were used together. Placement of a rectangular collimator was effective in reducing operator professional exposure and public exposure to 20% while a backscatter shield was not effective in reducing public exposure [8].

Gonzales et al., evaluated the dose of scattered radiation in the body organs of an operator and assistant


**Figure 6.** Positions of the handheld device and operator hands during acquisition: a) device parallel to the ground and close to the operator, b) device away from the body with fully outstretched hands (approximately 40 cm) and parallel to the ground, c) device perpendicular to the ground with partially outstretched hands
*Source:* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4846146/

located in different positions within the dental office when using a handheld portable device. 10 scenarios of different placement of the lead apron were simulated. The results showed a significant increase in operator dose due to angulation, and the minimum dose received by an assistant is shown at a distance of 2 meters and 45° from the direction of the X-ray beam, with a significant reducing personal dose using a lead apron [9].

Makdissi et al., examined the level of received operator dose when using the NOMAD Pro™ handheld device in different positions for the most exposed parts of the operator body, and when a thermoluminescent dosimeter was placed on a phantom near the eyes, thyroid, trunk, waist, arms and feet. Three research methods were performed by positioning the handheld device and the operator hands: parallel to the ground near the seated patient, parallel to the ground when the arms are outstretched, and perpendicular to the ground with partially outstretched arms (Figure 6). The highest radiation dose was measured on the left palm when the device was held perpendicular to the ground with arms partially outstretched. Variations in the level of radiation exposure to different parts of the operator body were affected by the position of the handheld device and the direction of the main beam of radiation. The shape and the size of the radiation protection zone obtained by the shield from scattered radiation will vary depending on the height of the operator, the length of the hands, i.e. the distance of the device from the operator and the angle at which the device is directed, which manage the direction of the main beam and consequently the amount of scattered radiation. Furthermore, it is stated that the patient's head must be tilted down for acquisition of the anterior maxilla and upward for acquisition of the anterior mandible. When this step is not taken, the downward angle of the upper jaw acquisition results in increased exposure of the operator's abdomen/gonads, while the upward angulation of the mandibular acquisition results in increased exposure of the operator's thyroid. The training of the operating personnel can influence the exposure to radiation doses when using the handheld device [10].

## The radiographic image control quality when utilizing X-ray handheld device

Lommen et al., examined the parameters of an image control quality of 80 intraoral images taken with the NOMAD Pro 2 handheld device and the wall mounted fixed Heliodent Plus device, according to the main parameters of the radiological dental image like the centeredness of the image, i.e. the corresponding tooth and the perpendicularity of the emitted radiation to the digital intraoral sensor (Figure 7, 8). Free image processing software was

**Figure 7.** The aquisition mode with the handheld device (left) and the wall mounted device (right) in the study by Loomen et al.
*Source:* https://www.sciencedirect.com/science/article/pii/S1013905221001176

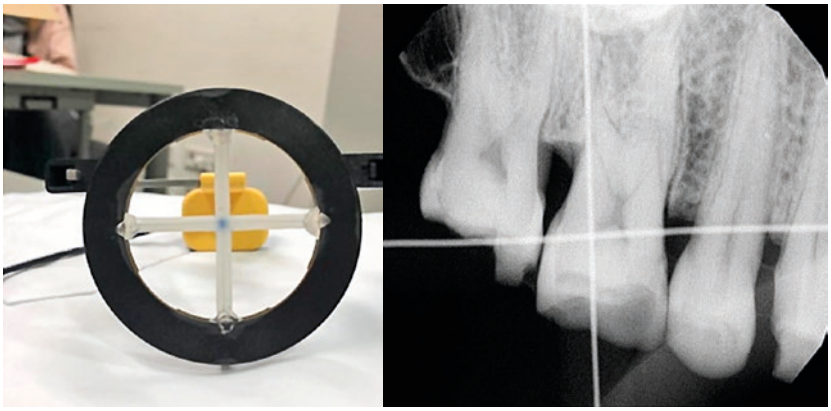

**Figure 8.** A centrally placed target that is clearly visible when the image of the upper right first molar is centered and taken vertically
*Source:* https://www.sciencedirect.com/science/article/pii/S1013905221001176

used to analyze the horizontal and vertical deviation in millimeters (mm), pixels (px), and angular degrees (°) from the initially calibrated parameters (Figure 8). Scattering from centeredness (mm and px) is rated as the degree to which devices generate usable images. Angular deviation from verticality was assessed as the degree to which the devices generated accurate images. The results showed a high accuracy in the positioning of the image for the handheld device Nomad Pro 2 and the wall fixed Heliodent Plus. However, scattering from the image center was significantly less using the wall mounted device compared to the handheld device. With caries diagnostic guidelines with a maximum tolerance of ±7° in image angulation to the sensor plane, the results of the study are in accordance with the guidelines (van der Stelt et al., 1989) so clinical trials are needed on patients and not on models, necessary [11].

Pittayapat et al., examined the quality of the image with different devices (handheld portable: AnyRay, NOMAD, Rextar and wall-fixed MinRay) and several different types of sensors (Vistascan phosphor plate, SIGMA M CMOS sensor, VistaRay CCD sensor and Sopix CMOS sensor) [10, 11]. The combination of the NOMAD device with the phosphor plate system or the Rextar device with the Sopix CMOS sensor achieves the best diagnostic interpretation of the radiological image. The best results were achieved by the combination of an phosphor plate and NOMAD device. This is contributed by the fact that the phosphor plate has a spatial resolution of 22 lp/mm, and there is a longer distance from the end of the X-ray tube to the focus and a high range of gray scale. Compared to other devices, the NOMAD device has the smallest anode focal spot of 0.4 mm, which contributes to the sharpness of the image. The combination of the Rextar device with the Sopix sensor has proven to be useful in unexpected situations, such as national disasters [12].

Nitschke et al., determined whether the handheld NOMAD Pro 2 could produce equivalent radiographic image quality compared to the wall mounted Heliodent Plus system based on objective image quality parameters using dental phantoms. Image quality parameters such as distortion, level of detail, image size, overlay, resolution and technical parameters such as the distance from the end of the tube to the focus, were compared based on

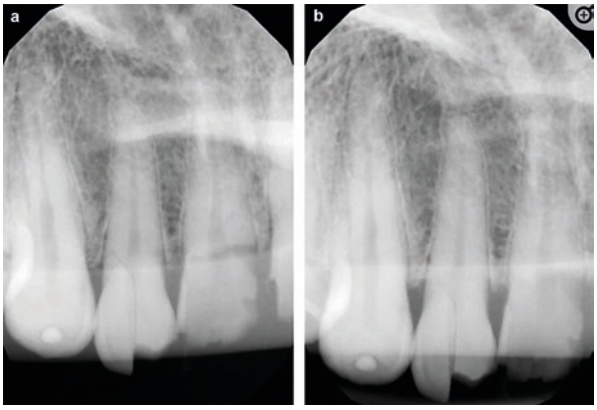


**Figure 9.** a) Image of the upper right canine, taken with the handheld device, b) image of the upper right canine, taken with the wall mounted device
*Source:* https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7985112/

the knowledge of different operators (dentists, dental students and dental assistants). As expected, dentists show a slightly better advantage in reporting of premolars in both device variants, while dental assistants were better than dental students in reporting maxillary premolars on images obtained with the wall system. No evidence was found of inferior quality with the utilization of the NOMAD Pro 2 handheld device, and the authors believe that it could be useful in the treatment of special patient groups in nursing homes or hospitals (Figure 9). Also, the operator should be allowed to manipulate the histogram or change the display settings such as contrast and brightness, because being disabled can mask differences between the two modalities [1].

## Conclusion

The development of the X-ray handheld portable device for intraoral imaging allows easier utilization in the surgical center during operations, in nursing homes or in home care. However, the utilization of handheld devices in routine dental practice is not recommended due to the secondary radiation doses that the operator may receive

during acquisition. Protective means (lead shields on the device, wearing protective apron, rectangular collimation) have been shown to be effective in reducing the radiation dose to the operator, thereby increasing the protection against secondary radiation carried out with handheld devices. The utilization of personal dosimeters is highly recommended, in order to ensure continuity of exposure to low doses of radiation. Guidelines, training and protocols of the utilization of the X-ray handheld device must be followed and strictly adhered to as well as regular audits conducted to ensure compliance. Although the operator does not receive an excessive dose while using the handheld portable device, it exceeds the dose received by the operator while using the wall mounted device. If the handheld portable devices seemed to result in poor diagnostic imaging quality, there can be no justification for increasing operator exposure. Although studies have shown high accuracy of the quality of radiological image, additional research should be performed on humans, not on models and phantoms. ■

# Upotreba ručnog radiografskog uređaja za intraoralno snimanje u suvremenoj stomatološkoj praksi


## Sažetak

U posljednje vrijeme povećao se interes za upotrebom ručnih uređaja za intraoralno snimanje u suvremenoj stomatološkoj praksi. Na globalnoj razini, donesena je nekolicina dokumenata sa preporučenim smjernicama o korištenju ručnog uređaja za intraoralno snimanje. S obzirom da su preporučene smjernice oprečnog stava time su se potaknula dodatna istraživanja o opravdanosti korištenja ručnog uređaja u svakodnevnoj praksi. Cilj ovog članka je predstaviti opravdanost upotrebe ručnih uređaja kao alternative za zidne fiksne uređaje jer se provelo nekoliko studija koje su proučavale razinu zračenja koju prima operater, okolina i pacijent, te je naglasak bio i na provjeri kakvoće kvalitete radiološke snimke. Iako su se rezultati promatranja parametara kakvoće radiološke snimke kod obje vrste uređaja pokazali uspješnima, rezultati ispitivanja doze zračenja osciliraju te nisu u potpunosti prihvatljivi za operatera, okolinu i pacijenta ukoliko se ne poštuju sve smjernice zaštite od zračenja. Istraživanja bi se trebala dodatno provesti na ljudima, a ne na modelima i fantomima, prije nego se u potpunosti uvedu u svakodnevnu stomatološku praksu.


**Ključne riječi:** ručni; NOMAD; Heliodent; intraoralno; stomatologija; radiografija

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