The use of digital extraoral radiographic equipment in the dental office

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Paper based on a PhD thesis.

Abstract

This paper intends to give an overview of the literature on digital extraoral radiography as well as some recommendations for daily practice.

Introduction

Dental radiography has a remarkable place in the field of medicine, because, in contrast to other medical disciplines, practically each dentist personally makes his own radiographs. In most cases, the practitioner needs the radiographs immediately, as these often form an essential part of diagnosis and treatment strategies. Therefore, oral radiography should be as efficient as possible, in order to minimise the time and effort needed for production, interpretation and storage of radiographs.

Since many years, film-based radiographic systems have been used in oral health care. After irradiation, these films are chemically developed and they are interpreted on a viewing box. Afterwards, they are stored in the patient file where they can be retrieved for later use. Besides being environmentally unfriendly, chemical development can be time-consuming, especially in one-handed dentistry and when no automatic developer is available. Moreover, chemical development is technique sensitive[1,2,3] and over- or underdeveloped radiographs can obscure pathology. Manual storage and retrieval of film-based radiographs is also time-consuming and susceptible to mistakes.

Digital radiography has been introduced in dentistry in the late eighties (RadioVisioGraphy®, Trophy, Vincennes, France), and is replacing film-based radiography in a growing number of dental offices. The digital nature of these radiographs makes development, display and storage more user-friendly as it is for the most part automated. In addition, contrast and brightness can be adjusted and in most cases, pre-programmed filters for enhanced image interpretation are available, which to a certain extent can compensate for under- or overexposure. Furthermore, tools for digital length measurements are often included.

Analogue extraoral radiographic systems

Radiographs in dentistry can be divided into two main approaches: intraoral and extraoral projections. Intraoral radiographs, depicting a limited number of teeth and their surrounding structures, can be acquired using a small film-pack which is placed inside the patient's mouth and irradiated using an intraoral radiation tube which is placed extraorally. Extraoral radiographs on the other hand show a larger part of the skull. These are acquired by means of a film outside the patient's mouth on the opposite side of the extraorally positioned radiation unit. In order to reduce the amount of radiation needed to produce extraoral analogue radiographs, films are inserted in cassettes, where they are clamped between two intensifying screens. The phosphor particles on these intensifying screens absorb part of the radiation and emit this radiation as visible light. The film, which is sensitive for both radiation and light energy, thus requires a smaller amount of radiation.

There are different extraoral projection techniques, of which panoramic and cephalometric radiographs are the most commonly used.

Digital panoramic and cephalometric radiographic systems

Digital radiographs can be acquired using two different sensor types, a Charge-Coupled Device (CCD) or a Storage Phosphor Plate (SPP). These sensor types are used both for intraoral and extraoral projections, although specific modifications are made for extraoral applications, especially for the CCD sensor-based units.

CCD sensors for radiography are composed of an array of radiation-sensitive elements, transforming radiation energy into electrical signals, which are sent to the computer and translated into a radiographic image on the computer monitor. CCD-based radiography is also called direct digital radiography because the radiographic image appears almost immediately on the computer monitor. Due to technical and financial limitations, CCD sensors have limited dimensions (max. 5 cm x 5 cm). The CCD sensor is an integrated part of the extraoral radiation unit (figure 1).

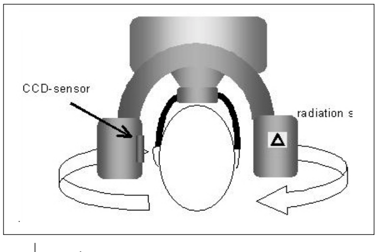

Figure 1

The CCD sensor of a direct digital panoramic unit is integrated in the radiation unit, sending the translated radiation energy immediately to a computer

SPPs are composed of a plastic base plate, covered with phosphor particles. These particles can capture radiation energy and store it for a certain time. When these SPPs are scanned by a fine laser beam, the radiation energy is released as light energy, which is multiplied, measured and transformed into electronic signals (figure 2). These signals are sent to the computer and the radiographic image appears on the monitor. Because of the delay caused by the scanning procedure, this digital radiographic technique is also called indirect digital radiography. In contrast to CCD sensors, SPPs can be manufactured in different sizes, comparable to the analogue film sizes (figure 3).

Figure 2

Scanning system for extraoral storage phosphor plates (ADC Solo®, Agfa, Mortsel, Belgium).

Figure 3

Storage phosphor panoramic cassettes consist of a cassette without intensifying screens and a storage phosphor plate.

Digital panoramic radiographs

Panoramic exposures are acquired using narrow beam radiography. This means that a narrow radiation beam moves around the head, thus exposing the structures in question progressively. Simultaneously, the cassette head holding the image receptor moves around the head at the opposite side. This technology is developed in order to be able to image the curved jawbone on a flat receptor with minimal overlapping of structures. For every jaw segment exposed, the radiation beam enters the maxillofacial structures as perpendicular as possible.

Analogue and digital panoramic exposures follow the same imaging principle, except for the fact that the film cassette which is used for analogue imaging is replaced by a CCD sensor for direct digital radiography or with a digital storage phosphor plate cassette for indirect digital radiography. For CCD-based imaging, the CCD sensor is integrated in the radiation unit and replaces the cassette holder.

Digital cephalometric radiographs

Cephalometric radiographs are obtained with a stationary radiation source and image receptor.

For indirect digital technology, a cassette without intensifying screens is used, containing a storage phosphor plate of similar dimensions as an analogue film. For both analogue and indirect digital cephalometric radiographs, a very short exposure time is applied. However, when using direct digital radiographs, a different approach is needed because of the limited size of the CCD sensor. Therefore, a linear scanning procedure is used, exposing the skull in a stepwise manner. Very recently, however, a "One Shot" direct digital cephalometric exposure technique has been introduced by Trophy (Trophypan C®, Marne-la-Vallée), reducing the exposure time and risk for movement artefacts considerably. The system should be brought on the market at the end of 2003.

Current status of digital panoramic and cephalometric radiographic systems

Panoramic radiography

In 1985 Kashima et al.[4] reported on a prototype imaging plate (indirect digital) system for panoramic radiography. They stressed already the potential advantages of wide latitude, image processing and exposure reduction. McDavid et al.[5] introduced a prototype of a CCD-based (direct digital) panoramic radiography system in 1991 that they installed on an existing Orthopantomograph® radiation unit. In a preliminary experimental set-up and after further testing on test phantoms, a phantom head and a human subject[6,7], the digital system was found comparable to analogue radiography both for physical properties such as density, contrast, magnification and distortion and most factors of diagnostic image quality (except trabecular bone representation for the clinical subject and depiction of cementoenamel junction for the phantom).

One of the first commercialised digital panoramic units, the OP100 Digipan® (Trophy Radiologie, Vincennes, France and Instrumentarium, Tuusula, Finland) has been evaluated by Farman et al.[8,9]. Image layer, resolution and magnification factors have been described in detail. A dosimetric evaluation was performed with an ionisation chamber and indicated entry dose savings of around 70% compared to analogue radiography. A clinical trial[10] showed a comparable performance of digital and analogue radiographs.

Dula et al. (1998)[11] evaluated the Orthophos DS® direct digital panoramic unit for the detectability of radiolucent lesions. Artificial defects were made in hemisected mandibles surrounded with soft tissue equivalent material. Organ doses were measured with TLD dosemeters on a phantom head. It was found that exposure settings could be lowered and a dose reduction of up to 43% could be achieved thanks to the adjustment of contrast and density which is automatically made by the imaging software. The same experimental set-up was used by Sanderink et al.[12] to compare the diagnostic performance for detection of artificial radiolucencies of compressed and uncompressed panoramic radiographs. A compression of 1:28 of the data did not affect the diagnostic image quality for the diagnostic task described above.

Schulze et al.[13] evaluated digital measurements on direct digital panoramic radiographs (Orthophos DS®) and concluded that these were reliable for clinical applications.

Gijbels et al.[14] compared the diagnostic image quality of analogue and direct digital (Orthophos DS®) panoramic images. Crestal and periapical bone regions were evaluated and the need of additional periapical radiographs to allow diagnosis was indicated. They found direct digital panoramic radiographs to be inferior to analogue radiographs. Diagnostic image quality of digital radiographs could, however, be improved by application of a "contrast enhancement" filter.

Ramesh et al.[15] compared analogue and direct digital (Orthophos DS®) panoramic radiographs for detection of caries and marginal periodontal bone loss. They found comparable results for caries detection and inferior results for periodontitis detection for the digital system.

A very recent study[16] evaluated the effect of dose reduction on diagnostic image quality for direct digital panoramic radiography (Orthophos DS®). A dose reduction of 40-50% was reached without altering the diagnostic image quality.

Except for the prototype introduced by Kashima et al. in 1985[4], evaluation of the diagnostic image quality of indirect digital panoramic radiographs has been evaluated by Gijbels et al.[17]. They found the diagnostic image quality of indirect digital panoramic radiographs, acquired with the ADC Solo® SPP system (Agfa, Mortsel, Belgium), to be comparable with analogue panoramic radiographs for a number of specified diagnostic tasks.

Cephalometric radiography

For cephalometric radiography, storage phosphor plates have been used more extensively. Seki and Okano[18] and Näslund et al.[19] showed that the Fuji® (Fuji Medical, Tokyo, Japan) indirect digital system required a lower radiation dose for cephalometric radiography without loss of diagnostic image quality. Agfa (Mortsel, Belgium) has also developed a system readily available for limited imaging centres (ADC Solo®). This system has been evaluated for oral imaging by Gijbels et al.[20]. They found a significantly higher diagnostic image quality for digital cephalometric radiographs compared with analogue radiographs for the detection of cephalometric landmarks. The interobserver agreement was also higher for digital radiographs.

Direct digital cephalometric radiography has been investigated by McDavid et al.[21]. Contrast and resolution seemed adequate to perform diagnostic tasks. They stated that the linear scanning technology used to construct the image increased contrast by reducing the amount of scatter radiation. Visser et al.[22] compared radiation doses of analogue and direct digital (Orthophos DS Ceph®, Sirona Dental, Bensheim, Germany) cephalometric radiographs. They found that an average dose reduction by a factor of two could be achieved by using direct digital cephalometric radiography.

A new prototype for direct digital radiography, called Direct Radiography® was introduced in 1998 by Sakurai et al.[23] The system was based on a relatively large (178 mm x 213.5 mm) TFT (Thin Film Transistor) panel and eliminated the need for a scanning procedure as in CCD-imaging due to the limitations of the CCD sensor size. Initial evaluation of the system showed a good spatial resolution and radiation sensitivity.

Recommendations for daily practice

Indirect or direct digital extraoral radiography?

As both indirect and direct digital extraoral imaging systems seem to be adequate for diagnostic purposes, the eventual choice depends on personal preference and organisation of the dental office. When there is already an extraoral radiation unit, which is satisfactory, it is probably easier to switch to indirect digital radiography, because the existing radiation unit can be used. In this case, it is enough to switch the analogue film-screen cassettes to digital phosphor cassettes, which do not contain intensifying screens. Of course, a scanner and dedicated software is needed to read out the radiographs. In case one prefers direct digital imaging, it is most likely that the existing radiation unit has to be renewed, although in some cases, analogue radiation units can be converted to direct digital systems. When, on the other hand, one wishes to renew an existing radiation unit or when a first extraoral unit is to be bought, personal preference will be the main motive. The direct appearance of the radiograph on the computer monitor with a CCD-based unit will perhaps be a plus for some practitioners. For cephalometric radiographs, however, a longer exposure time is needed because of the linear scanning procedure. This increases the risk for movement artefacts, especially for young children.

Storage of digital extraoral radiographs

Because digital extraoral radiographs require a large amount of storage space (usually more than 1 MB), a backup system with sufficient memory capacity is needed. Magnetic storage systems, such as ZIP® drives (Iomega, UT, USA) or portable hard disks as JAZ® drives (Iomega) will do, as will optical CD-Rom writers. When compression of radiographic data is required, care should be taken to preserve the diagnostic image quality.

Viewing of digital extraoral radiographs

When digital radiographs are diagnosed on the computer monitor, the surrounding light should be dimmed to increase contrast. External light sources should not cause reflections on the screen, which can compromise diagnosis. In order to achieve optimal settings of contrast and brightness of the computer screen, a test pattern can be used (figure 4). Furthermore, the screen resolution should be adapted to the resolution of the digital images. When digital extraoral radiographs are viewed on a low-resolution monitor, only parts of the image can be viewed unless it is zoomed out, which makes an overall appreciation of the radiograph difficult. When a colour monitor is used, settings should be at least 24-bit, because otherwise, not the full 256 grey value scale can be shown.

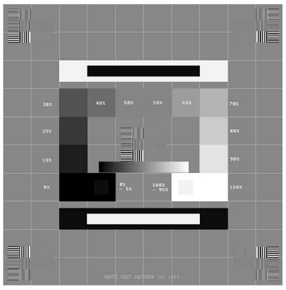

Figure 4

Test pattern to optimise contrast and brightness settings of computer monitor (SMPTE, Society of Motion Picture and Television Engineers, NY, USA)

Printing of digital extraoral radiographs

Although diagnosis of digital radiographs should be performed on the computer monitor, it is sometimes indispensable to print image data, for example for referral to a colleague. Technically, it is possible to print radiographs with minimal loss of diagnostic image quality, for example with a dry imager (figure 5). These printing devices produce radiographic images on a transparent film, which are very much comparable to analogue radiographs. They are, however, rather expensive and usually not affordable for a private dental office. In most dental practices, however, digital radiographs have to be printed only very occasionally. A cost-effective option would then be a colour inkjet printer. Reasonable results can be achieved when high gloss paper or transparencies are used and when the radiographs are printed in colour[24]. Colour prints indeed seem to be able to yield a wider range of grey values than images composed of only black and white values. When printouts are required more often, however, the consumption of inkjet cartridges and special paper can be quite expensive.

Figure 5

Dry imager for hard copy output of radiographic images on transparent film (Drystar 2000®, Agfa, Mortsel, Belgium).

Conclusions

For panoramic and cephalometric exposures, both indirect and direct digital systems seem to be adequate for diagnostic purposes. Physical properties are comparable to analogue radiography and dose savings can be achieved by lowering exposure settings. When interpreting digital radiographs on the computer monitor, care should be taken to optimise monitor settings and ambient light conditions. When radiographs have to be printed, a cost-benefit analysis can help to make a choice between printer types.

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