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Comparative evaluation of two digital technologies for dental radiographs: CCD-sensor (Sidexis®) versus sensor plate (Digora®)

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Authors: Thomas Hilgart, Ralf Schulze, Frank Schalldach, Bernd d'Hoedt
Dept. of Oral Surgery, Johannes Gutenberg University Mainz, Germany

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Introduction

To fulfill the recommendations of the IRCP to reduce radiological exposure dose, the required diagnostical information of the image should be obtained with a minimum of radiation. This objective can be achieved by the utilization of digital radiographic systems. Different technological philosophies for the acquisition of digital radiographs lead to two major solutions: CCD-sensor and storage phosphors (= sensor plate).
CCD sensor devices operate with a wire connected imager consisting of high-grade crystalline silicon in which neighboring atoms are covalently bonded. Radiation breaks this covalent bonds and generates electron-hole pairs, which are collected in a conductive gate structure. This information is read out by changing gate potentials across the two dimensional array from row to row. The resulting amplified electronic signal represents the sequence of charges being read out and is digitized and decoded as gray level values (Welander et. al 1993 [1]).
Sensor plates are capable of storing the energy absorbed in quasistable states, when excited by x-rays and of emitting luminescence radiation corresponding to the absorbed energy when stimulated by visible or infrared radiation (Sonoda 1983 [2]). The basic physical principle is the capability of x-rays to elevate electrons in the storage material on a higher metastable level. The information is read out by a laser scanner and subsequently absorbed in a photomultiplier. Hereafter the analogue signal is digitized and then visualized in gray levels. The active layer of the Digora®-system consists of $BaFBr:Eu^{2+}$ compounds in a phosphor matrix.

Objective

Aim of the study [3] was to compare a CCD-based technique (Sidexis®) with a sensor plate operated method (Digora®) in vitro and in vivo. Additionally both systems were compared to a high performance conventional film (Ektaspeed-Plus®/Kodak).

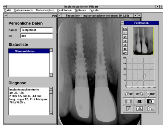

Fig.1: Desktop: Digora®

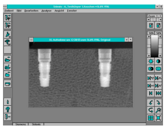

Fig.2: Desktop: Sidexis ®

Material and Methods

The following physical parameters were evaluated :
1. Spatial resolution: Resolution was expressed in Lp/mm and measured by means of a testing device containing convergent linepairs in a lead foil (Linienprüfkörper der Firma Funk, Erlangen, Germany). Maximum measurable resolution of the device was 20 Lp/mm. All digital measurements were performed in enlarged screen magnification (2:1).
2. Distortion effects: Line grids, round and spherical metallic objects were exposed. Magnification factors were determined to obtain information about the extent of distortion.
3. Permanence of stored information on sensor plate: Signal loss 12h and 24h after exposure was measured as a function of noise.
4. Noise: This parameter was evaluated for both digital devices with a set of 26 plain radiographs per device in a graduated sequence of exposure data (0.02-0.4 sec. at 60kVp/70kVp). The following mathematical expression of Künzel and Benz [4] was employed (Fig.3):

$$\sigma_{total} = \sqrt{\frac{\sum_{i=1}^{n_{total}} xi^2 - \frac{\left(\sum_{k=1}^{n_{total}} xk\right)^2}{n_{total}}}{n_{total}}}$$

Fig. 3. Mathematical expression of Künzel and Benz

To exclude marginal artifacts standard deviations were calculated merely for the central 50% area of the total image surface. The images were digitally evaluated with a modified version of a TIFF-reading routine (Born, 1996 [5]).
5. Image quality in vitro: Standardized periimplant defects at dental implants (Frialit® 2, FRIATEC AG, Mannheim, Germany) inserted in rectangular bovine spongious bone blocks applied for the experimental setup (Fig.4). Defects were measured repeatedly by one examiner and the resulting values were statistically analyzed.

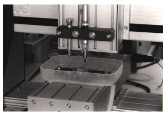

Fig. 4: CNC drilling device for the periimplant defects

6. Clinical applicability: 73 radiographs of 51 patients were performed with both digital systems (n = 40 with Digora® , n = 33 with Sidexis®). Compared was the handling of both systems in different clinical applications.

Results

1. Spatial resolution: Maximum resolution was 8 Lp/mm for Digora® and 11 Lp/mm for Sidexis®. The resolution of the Ektaspeed plus film exceeded the measurable resolution of the testing device (20 Lp/mm).
2. Distortion effects: In this study distortion errors occurred alongside the storage plate (Digora®) with an approximate value of 7%. Such errors were not encountered for the CCD-detector and the conventional film.
3. Permanence of stored information on sensor plate: 12 hours post exposure standard deviations increased at 109%, and afterwards remained steady within the next 12 hours.
4. Noise: Noise of the CCD-system exceeded that of the sensor plate. Minimum noise values for Sidexis® were reached at 60kVp and 0.1 sec, whereas the sensor plate exhibited roughly consistent values over a wide range of exposure times (Fig. 5a,b). Sensor artifacts were encountered for the CCD-device at 70kVp: 0.12-0.4sec and 60kVp: 0.16-0.4 sec.

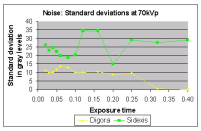

Fig. 5a: Standard deviations noise at 70kVp

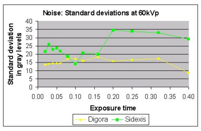

Fig.5b: Standard deviations noise at 60kVp

5. Image quality in vitro: Defect measurements were neither significantly dependent on the digital technique nor on exposure time but on the internal structure of the bone blocks.
6. Clinical applicability: The handling of the storage phosphor plate was very similar to a normal film and therefore superior for intraoral applications compared to the CCD-sensor.
7.Dose reduction: Due to shorter exposure times a noticable reduction of radiation dose (50-75%) is achieved by both digital systems compared to the film-based technique.

Discussion and Conclusions

Discussion: Our results are based on the evaluation of two specific systems, Sidexis® and Digora®. Thus they do not automatically apply for other sensor-plate or CCD-detector devices. In our experiment the CCD-based system proved to have a higher spatial resolution and minimal linear distortion compared to the sensor plate. However, it is questionable, how far the differences are clinically relevant. On the other hand the storage phosphor plate exhibited a wide dynamic range and therefore is less liable to errors concerning exposure time and voltage. This results in an obvious reduction of radiation dose, particularly in comparison to the film-based technique. Clinical applicability of the sensor plate for intraoral exposures was superior to the CCD-sensor and was very similar to the conventional film.
Conclusion: The results of our study suggest, that the sensor plate system (Digora®) is favorable to the CCD-detector (Sidexis®) for its easier handling, radiation reduction and superior image quality. Both systems are capable to produce sufficient images for clinical applications and lead to clear dose reduction in comparison to the film-based technique.

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Abbreviations

Lp = Linepair CCD= Charged Coupled Device IRCP= International Commission on Radiological Protection

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Correspondence address:
Dr. Ralf Schulze
Univ.-Poliklinik f. ZÄ.Chirurgie
Augustusplatz 2
D - 55131 Mainz

Poster Faksimile: