

Intraoral Radiology in General Dental Practices – A Comparison of Digital and Film-Based X-Ray Systems with Regard to Radiation Protection and Dose Reduction

Die intraorale Radiologie in allgemein Zahnärztlichen Praxen. Ein Vergleich digitaler und analoger Systeme im Hinblick auf Strahlenschutz und Dosisreduktion

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Key words

- intraoral radiology
- digital imaging
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Zusammenfassung



Ziel: Die Untersuchung soll mehr Einblick in die Verbreitung und Anwendung der digitalen intraoralen Röntgentechniken in allgemein Zahnärztlichen Praxen liefern und diese im Bezug auf die Reduktion der effektiven Patientendosis mit film-basierten Systemen vergleichen.

Material und Methoden: 1100 Fragebögen wurden an niedergelassene Zahnärzte verteilt. Die Auswertung der Daten erfolgte systembezogen mithilfe der deskriptiven Statistik und nicht parametrischer Tests nach Kruskal-Wallis und Mann-Whitney sowie dem Chi-Quadrat-Test (SPSS 20).

Ergebnisse: 64% der befragten Zahnärzte röntgen analog, 23% röntgen Speicherfolien- und 13% Sensor basiert. Eine erhöhte Behandlerzahl korreliert stark mit der Verwendung digitaler Geräte. Fast 3/4 der analogen Gruppe arbeiten mit E- oder F-Speed-Filmen aber 45% lehnen einen Wechsel zu digitalen Systemen ab. Die Bleischürze wird von allen Gruppen konsequent genutzt, während Schilddrüsenschutz und rechteckige Blenden nur von der Minderheit angewandt werden. Eine bis zu vierfache Reduktion der Belichtungszeit von D-Speed-Filmen hin zu Sensoren ist zu beobachten. Die Summe an Zahnfilmaufnahmen durch Sensoranwender ist aufgrund der Detektorgröße und von Positionierungsschwierigkeiten signifikant erhöht. Die Aufnahmen pro Patient betrachtet ergeben jedoch nur eine positive Tendenz hin zu mehr Aufnahmen. Die Handhabung digitaler Systeme vor der Belichtung scheint tendenziell gleich schwierig oder schwieriger als die analoger Systeme, wohingegen nach der Exposition digitale Systeme favorisiert werden.

Schlussfolgerung: Trotz der leichten Erhöhung der Zahnfilmanzahl durch Sensorsysteme findet eine deutliche Reduktion der Strahlendosis statt. Für Speicherfolien kann, entsprechend der Abnahme der Belichtungszeit, von einer Dosisreduktion um die Hälfte ausgegangen werden. Positionier-

Abstract



Purpose: The purpose of this study was to gain insight into the distribution and application of digital intraoral radiographic techniques within general dental practices and to compare these with film-based systems in terms of patient dose reduction.

Materials and Methods: 1100 questionnaires were handed out to general dental practitioners. Data was analyzed with respect to the type of system by using descriptive statistics and nonparametric tests, i. e. Kruskal-Wallis, Mann-Whitney and chi-square test (SPSS 20).

Results: 64% of the questioned dentists still use film-based radiology, 23% utilize storage phosphor plate (SPP) systems and 13% use a charge-coupled device (CCD). A strong correlation between the number of dentists working in a practice and the use of digital dental imaging was observed. Almost 3/4 of the film users work with E- or F-speed film. 45% of them refuse to change to a digital system. The use of lead aprons was popular, while only a minority preferred thyroid shields and rectangular collimators. A fourfold reduction of exposure time from D-speed film to CCD systems was observed. Due to detector size and positioning errors, users of CCD systems take significantly more single-tooth radiographs in total. Considering the number of radiographs per patient, there is only a slight tendency towards more X-rays with CCD systems. Up to image generation, digital systems seem to be as or even more difficult to handle than film-based systems, while their handling was favored after radiographic exposure.

Conclusion: Despite a slight increase of radiographs taken with CCD systems, there is a significant dosage reduction. Corresponding to the decrease in exposure time, the patient dose for SPP systems is reduced to one half compared to film. The main issues in CCD technology are positioning errors and the size of the X-ray detectors

ungsschwierigkeiten und die Detektorgröße stellen die nicht leicht zu behebenden Hauptprobleme der Sensortechnologie dar. Hinsichtlich der Strahlenschutzvorkehrungen sind noch Verbesserungen vonnöten.

Kernaussagen:

- ▶ Verantwortungsvoll angewandt führt die digitale Radiologie auch unter Praxisbedingungen zu einer deutlichen Dosisreduktion.
- ▶ Nur durch die Umsetzung aller Strahlenschutzvorkehrungen wird die geringstmögliche Patientendosis erzielt.
- ▶ Es gilt den Einsatz Strahlen verringernder Methoden zu steigern.

Introduction

Digital radiology, established in dentistry during the 1980s, is nowadays considered to be as good as conventional film. In 2007 the ICRP [1] updated the radiation and tissue weighting factors for brain tissue, salivary glands, oral mucosa and extra thoracic airways based on the latest available scientific information. The risk-based study by Ludlow et al. [2] recommends further reducing X-ray usage in the head and neck area. The reduction of the dosage for digital compared to film-based radiology is generally accepted. Besides the well described advantages and achievements of digital radiology the ICRP publication 93 "Managing patient dose in digital radiology" [3] cautions against the risk of excessive use of X-rays due to digital techniques. Fast and easy image generation may lead to a relatively unnoticed increase of radiographs. The dose reduction of digital systems might be decreased by additional radiographs and incorrect exposure parameters. Even within the film-based system, dose reductions up to 50% are achievable by using high-speed films and radiation protection measures. The present study gives insight into the distribution and application of digital techniques in general dental practices in the district of Tübingen, Germany focused on radiation protection and dose reduction. For the different intraoral X-ray systems – film, CCD, SPP – the number and the acquisition parameters of the radiographs taken are to be compared. The usage of different dose-reducing measures and the practicability and ease of use of the two digital radiographs compared to the film-based system are to be evaluated.

Materials and Methods

Designed as a standardized questionnaire, survey forms were sent out via circular letter no. 1/2012 in February and 2/2012 in April and handed out with the final exam of the updating program of radiation protection in March 2012 in Neu-Ulm by the dental association of Tübingen, Germany. All 1100 resident dentists in the district of Tübingen were included. Data of orthodontists, assistants and pensionaries was discounted. Based on a literature search, 13 questions were selected. They served as the basis for the questionnaire. The collected data was gathered retrospectively in the table function of Microsoft Excel 12.0 (Microsoft Corporation, Redmont, USA) and displayed by methods of descriptive statistics. Statistical evaluation was made by IBM SPSS statistics, version 20 (IBM Corporation, Armonk, USA). The target dimensions were the questions of the questionnaire, which were

which are difficult to eliminate. The usage of radiation protection measures still needs to be improved.

Key Points:

- ▶ Responsible use of digital intraoral radiology results in a significant dose reduction in everyday practice.
- ▶ The ALARA principle is only achieved by strict implementation of dose-reducing methods.
- ▶ The efforts to use dose-reducing devices must be increased.

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analyzed by non-parametric Mann-Whitney and Kruskal-Wallis tests for 2 or k samples or tests for binomial distribution and chi-square tests for one sample. Linear correlation between two variables was verified by Pearson's correlation coefficient. The two-sided significance level with $\alpha=0.05$ was used for analysis. Differences $p<0.05$ were considered significant. Not all questionnaires have the same number of answered questions. All in all only the applicable answers were counted. Clearly wrong answers were discounted. The results were rounded to one decimal place.

Results

294 questionnaires were returned which means an overall response rate of 27.7%. 64% of those polled use film, 23% use storage phosphor plate (SPP) systems and 13% work with a charge-coupled device (CCD). The resulting 36% digital systems (63% SPP, 37% CCD) reveal that the majority of dentists still use film-based radiology in their practices. Even though there is no direct coherence between work experience and the type of X-ray system used, the increased number of digital systems in the group of 0–10 years of work experience implies that dentists who have been working for a shorter period of time are more likely to have a digital system. The increasing number of dentists working in joint practices was determined with a tendency towards digital systems ($r=0.997$; $p=0.003$). The average age of the X-ray systems (film-based 14.1, CCD 8.6 and SPP 6.4 years) differs significantly (<0.001). Lead aprons are used for radiation protection by 88.4%. More effective devices such as thyroid shields and rectangular collimators are only used by one-third, respectively one-fourth and are therefore neglected. Long cones and aiming devices are utilized by two thirds of the dentists. A lack of knowledge can be observed for rectangular collimation, thyroid shields and long cones. Users of digital systems, most of all users of SPP systems, use thyroid shields ($p=0.013$) and rectangular collimation ($p=0.006$) significantly more often than their colleagues with film-based X-ray systems. The exposure time for film ($\bar{\theta} 0.28$ s) is twice as high as the exposure time for SPP ($\bar{\theta} 0.14$ s) and 2.8 times higher than for CCD systems. Furthermore, there is a 40% difference in exposure time from SPP to CCD (Fig. 1).

The amperage for a single-tooth radiograph of an upper molar is comparable for the different systems ($\bar{\theta} 7.1$ mA), while the tube voltage is significantly lower for CCD-based systems ($p=0.019$). A reduction in exposure time is obvious comparing D- to E- and F-speed film. Almost 75% of the film users work with E- or

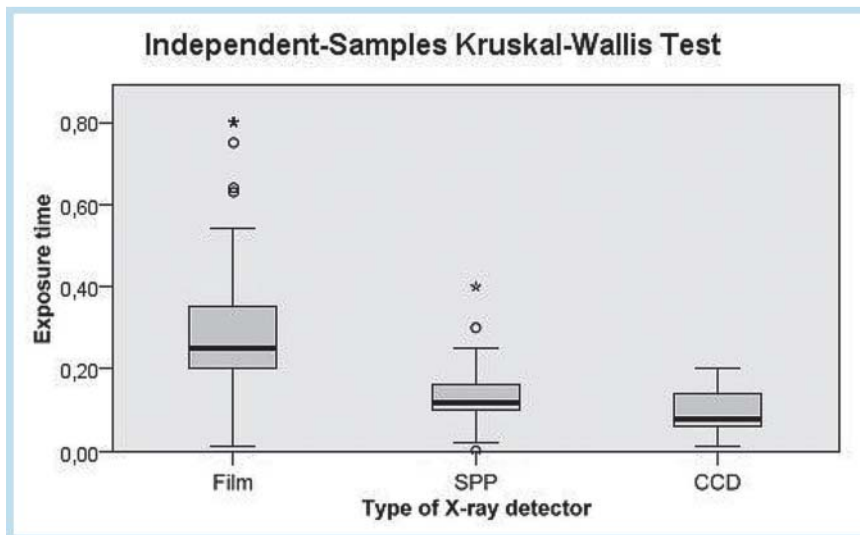


Fig. 1 Boxplot of the Kruskal-Wallis test illustrating the exposure time of an upper molar for film-based, SPP and CCD systems.

Abb. 1 Boxplot des Kruskal-Wallis-Tests zur Veranschaulichung der Belichtungszeit eines oberen Molaren unterteilt in analoge, speicherfolien- und sensorbasierte Systeme.

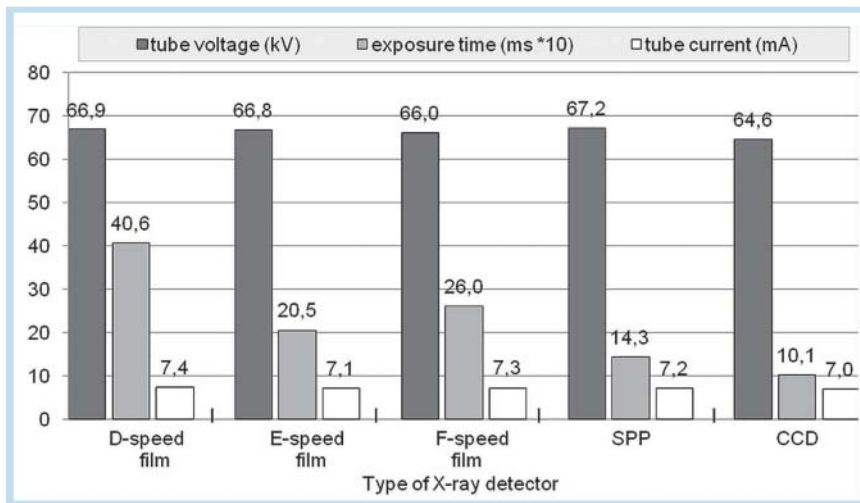


Fig. 2 Average values for tube voltage (kV), exposure time (ms*10) and amperage (mA) concerning the different X-ray detectors (D-, E-, F-speed film, SPP, CCD).

Abb. 2 Darstellung der berechneten Mittelwerte für die Parameter Röhrenspannung (kV), Belichtungszeit (ms*10) und Stromstärke (mA) bezüglich des verwendeten Röntgendetektors (D-, E-, F-Speed-Film, Speicherfolie, Sensor).

F-speed film. There is a significant negative correlation in exposure time from D-speed film to solid-state detector ($r=0.593$; $p<0.01$) and thus to understand that even under conditions of practice an up to fourfold decrease in exposure time is taking place (Fig. 2).

The total amount of dental films taken during one work week for CCD systems is significantly higher than for film-based systems ($p=0.007$), whereas no significant difference is to be observed by SPP systems. Regarding intraoral radiographs per person, there is a positive tendency towards more radiographs with CCD systems without the achievement of the significance level. Film-based and SPP systems performed quite similar (Fig. 3, 4).

Asked for the reasons for more radiographs owing to digital radiography, CCD system users named difficulties in detector positioning and retakes because of bad images. SPP system users mentioned faster image generation, lower radiation dosage and diagnostics. There seem to be no or only a few problems with detector positioning and only a few retakes with SPP systems (Fig. 5).

In contrast to dentists working with an SPP system using two or more sizes of X-ray detectors (88.1%), CCD system users often use only one typically small detector (59%). Handling digital systems up to image generation is equally or more difficult in comparison

to film-based systems, whereas image production, diagnostics, system maintenance and archiving seem to be easier. Storage phosphor plates appear to be equal or superior to conventional film, whereas CCD systems are linked to some negative aspects. It is mentioned as being superior to SPP systems in scanning only (Fig. 6).

45% of the dentists using film-based systems object to changing to a digital system. The main reason is cost (67%). One half is aware of the complexity of the subject and one fourth sees no advantage in changing.

Discussion

Literature doesn't give any information about the usage of intraoral radiology in German dental practices. The present work is intended to give an overview on the state of the art in intraoral radiology. The response rate of almost 28% involves the risk of a selection bias and limits the significance. The results have to be interpreted carefully and cannot be regarded as generally applicable. Compared to national and international data, the composition of the results seems to be very reasonable. A study from Kent, England refers to 49% usage of digital intraoral radiology

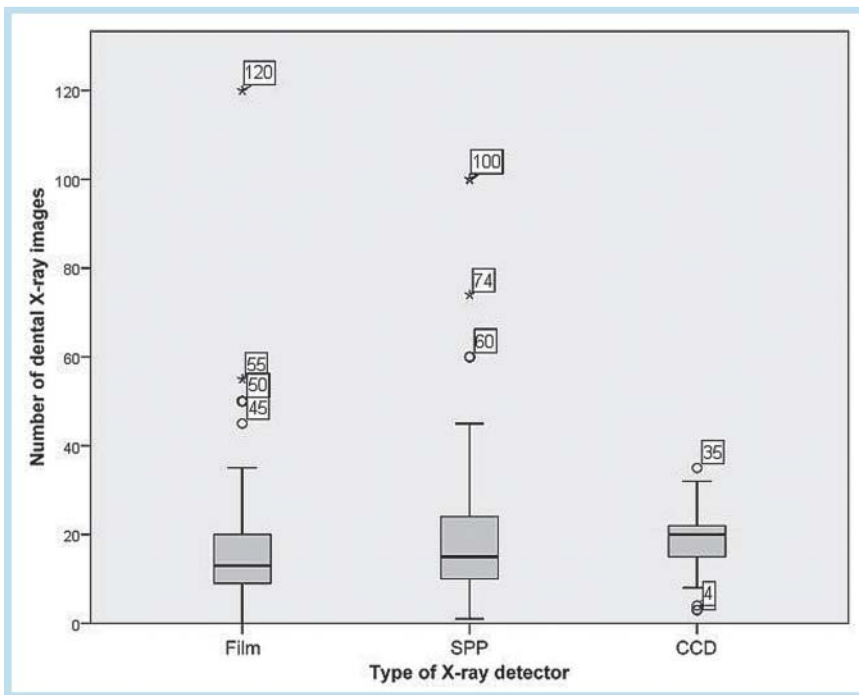


Fig. 3 Boxplot of the number of dental films taken during one work week for film-based, SPP and CCD systems.

Abb. 3 Boxplot zur Anzahl der in 5 Arbeitstagen angefertigten Zahnfilme für analoge, speicherfolien- und sensorbasierte Systeme.

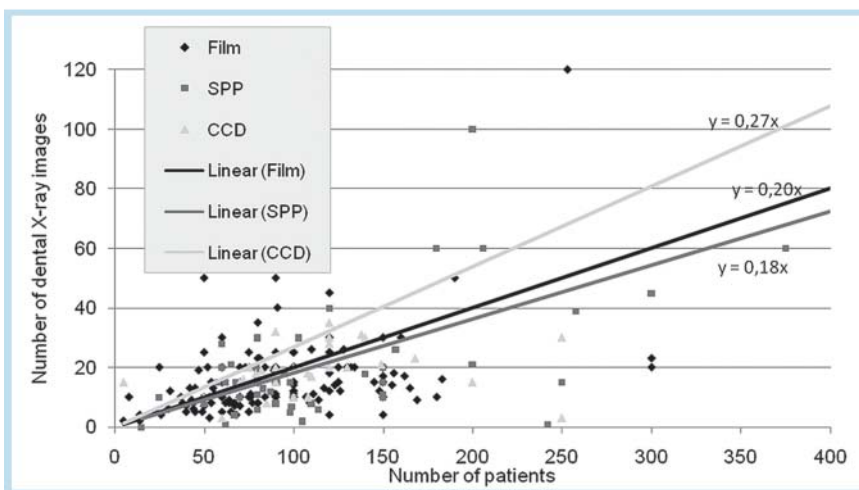


Fig. 4 Number of dental films taken during one work week in relation to the number of patients in the same period for film-based, SPP and CCD systems.

Abb. 4 Anzahl der innerhalb von 5 Arbeitstagen angefertigten Zahnfilme im Verhältnis zur Patientenanzahl desselben Zeitraums für analoge, speicherfolien- und sensorbasierte Systeme.

(55% SPP, 45% CCD) [4] and Aps appraises 38% digital radiology with 63% SPP systems in the region of Flanders, Belgium [5]. Regarding international publications, a division of two-thirds to one-third for SPP and CCD systems is to be observed in most cases. Data suggests that dentists with fewer working years are more likely to have a digital X-ray system. In 2001 Wenzel und Møystad couldn't find a link between the type of X-ray system used and the dentist's age or years in practice [6]. As already published in other studies, dentists are likely to have a digital system when working in a joint practice. Strikingly over half of the 287 evaluated X-ray systems are only 10 years old. Compared to the Belgian ones [5], the dental intraoral X-ray systems in Germany are more up to date. The average age of 11.6 years is lower than in Switzerland (average 14 years) [7] as well. Possible reasons might be legal obligations and surveillance by the dental radiology authority in Germany. Even though the gonadal dose caused by an intraoral dental radiograph is very low and the application

of a lead apron has only a minimal influence on further dose reduction, almost every dentist polled consistently utilizes lead aprons. It is still uncertain to what extent dentists are aware of the minimal dose-reducing effect of lead aprons and why especially this radiation protection measure is used so consistently. The application of a thyroid shield however achieves a 5–56% dose reduction for a perioapical X-ray status on a phantom and in clinical tests on adults a 33–84% lower skin dose in the thyroid area [8]. This shows the usage of a thyroid shield is strongly recommended. The advantages of rectangular collimation are dosage reduction to the patient of up to 60% and image quality improvement based on the minimization of scattered radiation. The underutilization of rectangular collimators adapted to the detector size may be caused by increased difficulties in positioning the X-ray tube with a collimator. In our study the dental profession in the district of Tübingen performed well in terms of radiation hygiene compared to the figures published in the inter-

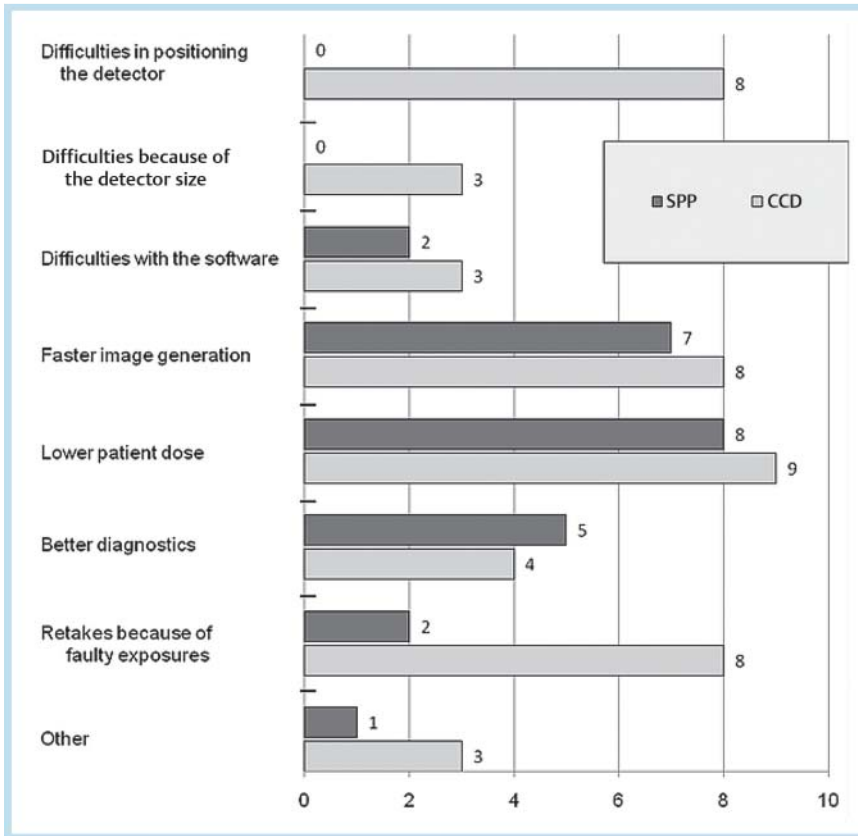


Fig. 5 Possible reasons for taking more intraoral radiographs for SPP and CCD systems.

Abb. 5 Darstellung möglicher Gründe für mehr intraorale Röntgenaufnahmen durch speicherfolien- und sensorbasierte Systeme.

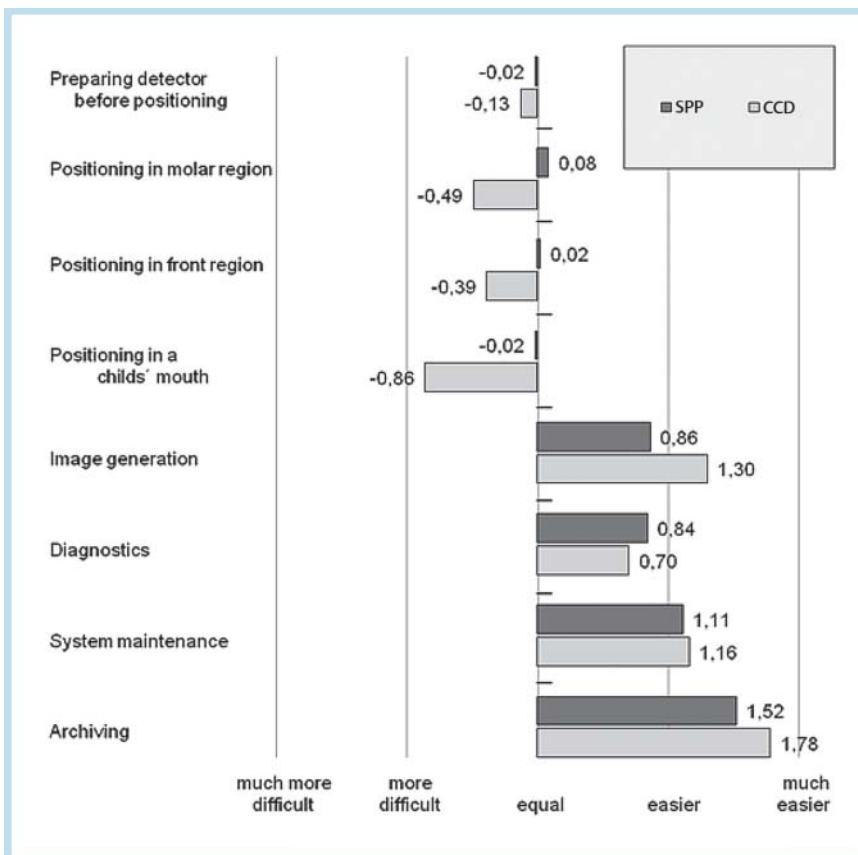


Fig. 6 User-friendliness of both digital techniques compared to film.

Abb. 6 Darstellung der Benutzerfreundlichkeit beider digitaler Systeme im Bezug auf analoge Systeme.

national literature. This might be an effect of the periodically required update courses, practice inspections and strict legal obligations. Good knowledge of radiation protection should lead to further dose reductions. However, there is still huge potential for further increase. One reason for the good performance of SPP users might be their increased sensitization, which has to be proved in further research. The usage of high-speed E- or F-speed films allows a dose reduction up to 50% compared to D-speed film. Therefore, all dentists should change to a fast speed film. Unfortunately despite the evident dose reduction 25% still use D-speed film.

The interaction of tube voltage, exposure time and tube current induces patient dose. The observed average values for tube voltage and tube current remain within the reference values of 60–70 kV and 7–8 mA. Linear decrease of exposure time from D-speed film to CCD system reveals that even under practice conditions a fourfold reduction is taking place. Similar results are published by Alcaraz et al. (60% time reduction) [9], Bhaskaran et al. (20–70%) [10], Hellen-Halme (51–75%) [11] and Wenzel and Møystad (55%) [12]. Blendl et al. claim that the digital system investigated in their study was at least twice as sensitive as the most sensitive film-based system [13]. An increase in exposure time by 40% for SPP compared to CCD systems can be seen in our data. The fear of vast overexposure of SPPs to create 'nicer' images could not be observed. [3] The work of Berkhou et al. from 2003 gave reason to study the number of X-rays taken during one week. They showed that users of CCD systems took on average 48.4 and SPP users 42.8 dental X-rays per week. With only 32.5 X-rays, film users took significantly fewer images in the same amount of time (–49% respectively –32%) [14]. Our data reveals that compared to film only CCD users take significantly more dental X-rays (+42%). The number of pictures taken by SPP system users is slightly higher (+7%) but doesn't reach the significance level. Mauthe and Eaton found no relation between dental digital radiology and an increased number of dental X-rays in general dental practices in West Kent, England [4] as well. In reference to the number of patients treated during the same period of time only a positive but no significant trend towards more X-rays with CCD systems was recognized. SPP and film-based systems however perform very similar. It can be assumed that the increase in dental X-rays for CCD systems is not as high as described by Berkhou et al. It is obvious that due to digital dental X-ray system, a dose reduction is taking place. Positioning errors and the size of the X-ray detectors are the main issues in CCD technology and are not simple to eliminate. For SPP systems these problems hardly occur. The utilization of only one sized and mostly small CCD detector for all cases makes imaging even more difficult. Berkhou et al. as well published that 70% of SPP and 50% of film users work with two or more detector sizes but 85% of CCD users have only one size [15]. The reasons for more dental X-rays in the SPP group by contrast could be easily reduced by disciplined behavior. The main reason for more X-rays in the Dutch study as mostly stated by CCD users was more diagnostic clarity (65%). Lower radiation exposure, errors, picture quality, additional earnings, dept reduction and marketing were also mentioned [14]. Compared to our dentists' statements

one might assume that the dental profession from Tübingen is more concerned about dosage reduction. The appreciably lower average of dental X-rays taken during one work week compared to the Dutch dentist's average 10 years ago confirms this. As Berkhou et al. [15] claim the handling of a digital system up to image generation seems to be as difficult or even more difficult than a film-based system. The following steps are easier. When it comes to SPP systems, there are only advantages regarding user friendliness and ease of use compared to film-based intraoral radiology, whereas some negative aspects of CCD systems can be observed. Only image producing is voted significantly easier for CCD than for SPP systems. Despite dose reduction and user friendliness, only a moderate interest in changing a film-based X-ray system to a digital one was revealed. A study of the Swiss dental profession recognized an even lower percentage (22%) [7]. Berkhou et al. recorded in 2002 a high intention to switch to a digital system in Dutch general dental practices (77%) [15].

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