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ORIGINAL ARTICLE



# Dentists' use of digital radiographic techniques: Part II – extraoral radiography: a questionnaire study of Swedish dentists

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**ABSTRACT**

**Objective:** The present study aims to gain knowledge about the dentist's use and choice of digital extraoral imaging methods, panoramic radiography and cone beam computed tomography (CBCT).

**Materials and Methods:** A questionnaire sent to 2481 dentists within the Swedish Dental Society contained questions about the panoramic technique and CBCT technique used, education, clinic size and type of service. The response rate was 53%.

**Results:** The study showed that 61% of the Swedish dentists had access to panoramic techniques and that 84% used a direct digital sensor, while 6% used storage phosphor plate techniques. Around 8% of the Swedish dentists had access to CBCT. It was also observed that group practices had two times higher odds of having panoramic equipment compared with solo practices. Approximately 40% of the dentists had undergone postgraduate education in oral radiology during the last 5 years. Dental nurses and dental hygienists exposed 92% of the panoramic radiographs and 75% of the CBCTs. Thirty per cent of those clinics with access to a panoramic unit exposed >30 panoramic radiographs per month and 56% of the clinics having access to CBCT did more than 75 examinations per year.

**Conclusions:** Today 61% of Swedish dentists have access to panoramic radiography and 8% have access to CBCT. There is a greater likelihood of having access if the dentist works in the public dental health service or in a group practice and if the dentist has undergone any postgraduate course in oral radiology.

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## Introduction

Since the introduction of digital radiography in dentistry in the late 1980s [1], digital imaging techniques have been used in a growing number of dental practices, for both intraoral and extraoral radiography [2]. Digital extraoral radiographic techniques within the dental field have evolved since the 2000s, and there are mainly three modalities used for extraoral radiography: panoramic radiography (PAN), cone beam computed tomography (CBCT) and cephalometric radiography. The cephalometric technique will not be addressed in this study. Current work is part 2 of the survey: 'Dentists' use of digital radiographic techniques. Part 1 has previously been published [3].

The PAN has long been a radiographic technique for imaging of teeth and jaws [4]. Digital panoramic techniques have been developed over the past 10 years and images can be achieved using either an indirect digital technique as storage phosphor plate (SPP) technique or a direct digital technique such as charged coupled device (CCD) or complementary metal oxide semiconductor (CMOS). The increase of PAN among dentists in Sweden over the last three decades has been significant. According to the Swedish Radiation Safety Authority, SSM (www.ssm.se), there are around 1300 panoramic x-ray sets in use by Swedish dentists in 2018.

The introduction of CBCT has been main advancement in dental radiology since the technology was introduced at the end of the 1990s [5] and has brought a great deal of interest in oromaxillofacial surgery, orthodontics and dental care [6]. The first dental CBCT was put into operation in Sweden in 2002 [7]. Registry data from the SSM 2018 show that there are 129 CBCT registered units in use in Sweden and some of them are combination equipment (PAN and CBCT). Since the appearance in the European market, a number of models have been introduced [8] having various imaging modes, resolution levels, field of view sizes and other technical parameters that affect radiation and image quality [8–11]. There is CBCT equipment for the patient's standing, sitting and supine positions, the most common being the standing position, as shown in a recent study, where about 66% of the clinics had a CBCT system for standing patients [4].

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Supplemental data for this article can be accessed here.

Further training after qualification for use of radiological methods are required by European radiation protection organizations, especially when using new equipment or technology [12,13]. Thus, everyone involved in radiography must have received adequate theoretical and practical training for radiological methods. In Sweden, a person responsible for panoramic equipment must have taken a special, certified training program, including both theoretical and practical training [14], and for dentists responsible for CBCT equipment, there are a number of requirements that must be met [5,12,14]. It was observed, however, that there is general lack of interest in dentistry by participating in courses in oral radiology [3,15]. In Part I of this survey it was shown that 60% of the Swedish dentists had not attended any continuing education course in oral radiology during the last five years [3], a deterioration over the last 20 years, as evidenced by Svenson et al. in the 1997 study, where 40% of dentists had not participated in a course in oral radiology [16]. All personnel involved in X-ray examinations must also undergo training necessary for the satisfactory performance of the work with regard to radiation protection according to the SSM (SSMFS 2008:31) [14].

Within Europe, the radiation protection organizations regulate who can perform X-ray examinations. For example, in Belgium each X-ray examination must be carried out by a dentist [17]. In a British survey over one-third of the dentists used unqualified staff to take panoramic radiographs [18]. Panoramic examinations in Sweden can in practice be performed by dentists, dental staff or auxiliary staff, but the decision whether or not to do an X-ray examination must be made by a dentist. A recent study showed that CBCT examinations in Sweden were mostly performed by dental nurses, in contrast to Norway, where only dentomaxillofacial radiologists, radiographers and specially trained dentists were allowed to perform CBCT examinations [7].

The size of the clinic can influence the type of X-ray equipment available and may have an impact on the choice of digital technique [19]. In a Belgian study PAN equipment was more commonly found in group practices, about 88%, compared to solo practices, 73% [20].

## Aim

The aim of the present study is to give insight into the use of digital extraoral radiographic techniques in public dental health services and private practices in Sweden. The focus is on the frequency of having access to the PAN/CBCT and factors affecting use.

## Material and methods

The study was approved by the Regional Ethical Review Board in Uppsala, Sweden (Dnr 2016/246) and was conducted according to the principles described in the Declaration of Helsinki.

### Design and data collection

The present study is designed as a questionnaire survey of dentists' use of panorama and CBCT technology. Official figures regarding the number of dentists in the Nordic countries show that in the year 2015 there were around 7700 dentists in Sweden; 54% ($n = 4137$) work in the public dental health service (PDHS) and 46% ($n = 3562$) in private practice (PP) [21]. At the planning of the study, we were given access to email addresses of dentists who were affiliated with the Swedish dental association (SDA) but not to dentists affiliated with the private practitioners' organization. We got access to data of 5209 registered dentists within the SDA. Selected were dentists between 23 and 70 years old and having valid email addresses, resulting in 4962 dentists. Fifty per cent of the 4962 dentists were randomly selected using the IBM SPSS Statistics (IBM Corporation, ver. 22, Armonk, NY) to participate, resulting in 2481 dentists to be included in the study [3].

### Questionnaire

A web-based survey tool, Esmaker NX3 (Entergate AB, Halmstad, Sweden), was used for sending the questionnaire. The survey was sent by email to all selected dentists, together with a covering letter in which it was emphasized that all respondents would be treated anonymously. The survey tool was programmed to automatically send two reminders at one-week intervals to non-responders. Dentists who answered the questionnaire are considered to have consented to participate in the study.

The questionnaire comprised a number of questions concerning demography and intraoral and extraoral radiography (PAN, and CBCT). Issues regarding the intraoral radiography were presented in a previously published study [3], while the present study focused on the extraoral techniques, PAN and CBCT. Both these sections comprised questions concerning the availability of equipment, type of detector, years in service, number of examinations, who performs the examinations, clinic size and dentist's postgraduate education. A battery of questions was designed to study the application of PAN and CBCT in dental practices. Some of the questions could be answered with either yes/no or an open alternative. For some of the questions, multiple answers could be given. To improve the one-way communication in questionnaire surveys, room for free comments was provided for all questions. The questionnaire is displayed in the Supplement.

A total of 1310 questionnaires were completed and returned, response rate 53%. Sixty-six respondents answered only the first question and were then referred to the demographic section, as they did not work with radiology in daily practice. In total, there were 1244 valid responses for the entire questionnaire. In Figure 1, a flow chart is displayed showing the process of selection from the available number of dentists in Sweden (7700) to the number of dentists included in the study (1244). Figure 1 is the same figure as published in Part I [3].

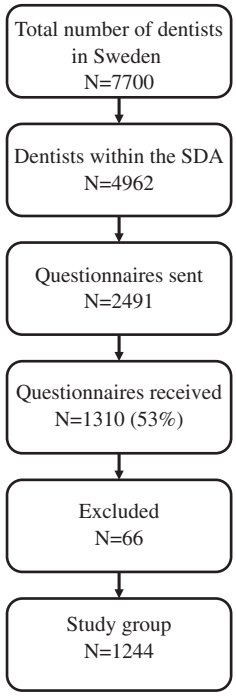


**Figure 1.** Flow chart from total number of dentists ($N = 7700$) to number of dentists included in the study group ($N = 1244$) [3].

Of the 1244 dentists who responded to the questionnaire, 479 (38%) were males and 765 (62%) were females; 850 (68%) dentists worked in the public dental health service (PDHS), and 394 (32%) were private practitioners (PPs); 775 (66%) of the dentists worked in group practices and 407 (34%) in solo practices; 992 (83%) were general dental practitioners (GDPs) and 198 (17%) were specialists.

### *Non-response analyses*

The known information on the 47% non-responders showed a very similar distribution in terms of age, sex, mean age and type of service, to that provided by the responders. A non-response analysis was made and showed no statistically significant differences with respect to gender ($p = .49$), age ($p = .14$) or type of service ($p = .07$). Mean age among the non-respondents was $47.5 \pm 13.1$ years, and for respondents, $48.2 \pm 12.6$ years. The numbers of answers to the different questions varied and were not analyzed any further.

### *Data processing and statistics/statistical methods*

SPSS was used for the analyses (IBM SPSS Statistics, version 22, Armonk, NY). The data were first processed by descriptive statistics, and then cross-tabulations were made for the two modalities PAN and CBCT against demographic data, using $Chi^2$ test. The variable 'clinic size' was dichotomized into 'solo' and 'group', where clinics with $\geq 3$ treatment rooms were considered as group practices (Table 1).

Three regression models were performed to analyze the effects of the following independent variables: service category (PDHS and PP), oral radiologist in the county, postgraduate education in oral radiology, gender, clinic size and years in service. Dependent variables were 'availability of panoramic equipment', 'availability of CBCT unit' and 'completed a postgraduate course in oral radiology during the last five years'. Data were checked for multicollinearity. *p* values were considered statistically significant at the .05 level.

**Table 1.** Frequencies for access to PAN/CBCT related to the variables 'service category', 'clinic size, 'years in service' and 'postgraduate education'.

| | Access to PAN $N = 1156$ % | Access to CBCT $N = 1155$ % |
|---|---|---|
| Study population in total | 61 | 8 |
| Service category | | |
| PDHS | 46 | 6 |
| PP | 17 | 2 |
| Clinic size | | |
| Solo | 17 | 2 |
| Group | 43 | 5 |
| Years in service | | |
| $\leq$20 years | 30 | 3 |
| $>$20 years | 31 | 5 |
| Postgraduate education | | |
| Yes | 28 | 5 |
| No | 33 | 3 |

$N = 1244$ (Missing data PAN = 88, CBCT = 89).

## Results

In Table 1 the relative frequencies are displayed for access to PAN and CBCT, related to the variables 'service category', 'clinic type', 'years in service' and 'postgraduate education'.

In total, around 61% of the respondent dentists had access to PAN, of whom 46% worked in the PDHS and 17% as PPs (of those working in PDHS, 66% had access to PAN, and of PPs, 52%). Of the panoramic units, 84% had a direct digital detector, 6% used an SPP detector and 1% used film. It could be noted that 9% of the dentists did not know what type of detector they used.

More dentists working in group practices had access to PAN than in solo practices, 43% versus 17% (of those working in group practices, 68% had access to PAN and in solo practices, 49%). In total 40% of the dentists had attended a postgraduate course in oral radiology (PDHS 38% and PP 43%).

CBCT was available to around 8% of the dentists, of whom 6% were PDHS dentists and 2% were PPs (of those working in PDHS, 8.3% had access to CBCT and in PP, 7.5%). In group practices 5% had access to a CBCT, compared to 2% in solo clinics.

### *Panorama and CBCT*

In Table 2 logistic regression models are shown presenting the adjusted odds ratios for having panoramic and/or CBCT equipment. It was found that dentists working in private practice were 40% less likely to have panoramic equipment compared with dentists working at PDHS. Dentists having a postgraduate education in oral radiology were 1.7 times more likely to have panoramic equipment and 1.9 times more to have CBCT compared to those with no postgraduate education. It was also observed that group practices had two times higher odds of having panoramic equipment

**Table 2.** Logistic regression models for having panoramic equipment and for having CBCT equipment as dependent variables.

| | Panoramic equipment | | | CBCT equipment | | |
|---|---|---|---|---|---|---|
| Independent variables | *p* | OR | 95% CI for OR | *p* | OR | 95% CI for OR |
| Working situation | | | | | | |
| PDHS reference | | | | | | |
| Private practice | .001 | 0.58 | 0.43–0.79 | .741 | 1.10 | 0.64–1.87 |
| Oral radiologist in the county | | | | | | |
| No radiologist reference | | | | | | |
| Yes radiologist | .308 | 0.78 | 0.48–1.27 | .629 | 0.83 | 0.39–1.77 |
| Postgraduate education | | | | | | |
| No reference | | | | | | |
| Yes | <.001 | 1.74 | 1.33–2.28 | .011 | 1.87 | 1.16–3.02 |
| Gender | | | | | | |
| Female reference | | | | | | |
| Male | .075 | 1.29 | 0.98–1.70 | .586 | 1.15 | 0.70–1.87 |
| Treatment rooms | | | | | | |
| Solo reference | | | | | | |
| Group | <.001 | 2.01 | 1.52–2.65 | .510 | 0.84 | 0.49–1.42 |
| CBCT equipment | | | | | | |
| No reference | | | | | | |
| Yes | <.001 | 26.14 | 6.36–107.47 | | | |
| Panoramic equipment | | | | | | |
| No reference | | | | | | |
| Yes | | | | <.001 | 27.52 | 6.66–113.68 |
| Years in service | | | | | | |
| >20 reference | | | | | | |
| ≤20 | .158 | 1.23 | 0.92–1.63 | .257 | 0.75 | 0.45–1.24 |

Odds ratios (OR), significance levels (*p*) and confidence intervals (CI) given.

**Table 3.** Logistic regression models for education as dependent variable.

| | Postgraduate education | | |
|---|---|---|---|
| Independent variables | *p* | OR | 95% CI for OR |
| Working situation | | | |
| PDHS reference | | | |
| Private practice | .081 | 1.30 | 0.97–1.74 |
| Oral radiologist in the county | | | |
| No radiologist reference | | | |
| Yes radiologist | .137 | 0.72 | 0.46–1.11 |
| Gender | | | |
| Female reference | | | |
| Male | .550 | 0.92 | 0.71–1.20 |
| Treatment rooms | | | |
| Solo reference | | | |
| Group | .526 | 1.09 | 0.83–1.44 |
| CBCT equipment | | | |
| No reference | | | |
| Yes | .008 | 1.90 | 1.18–3.06 |
| Panoramic equipment | | | |
| No reference | | | |
| Yes | <.001 | 1.75 | 1.34–2.29 |
| Years in service | | | |
| >20 reference | | | |
| ≤20 | .038 | 0.76 | 0.58–0.99 |

Odds ratios (OR), significance levels (*p*) and confidence intervals (CI) given

compared with solo practices. Clinics with CBCT equipment were 26 times more likely to have panoramic equipment compared with clinics with no CBCT.

### *Postgraduate education*

It was found that clinics with CBCT equipment were 1.9 times more likely to have dentists with postgraduate education compared with clinics without CBCT equipment. Also, clinics with panoramic equipment had 1.8 times higher odds of having a dentist with postgraduate education compared with clinics without panoramic equipment. Dentists with ≤20 years in service had 24% lower odds of having postgraduate education compared with dentists with more than 20 years in service (Table 3). Of dentists having access to a panoramic unit 46% had attended a postgraduate education course ($p < .001$), and of dentists having access to a CBCT, 59% ($p < .001$). Of dentists who had been in service for ≤20 years, 42% had attended a postgraduate education course, compared to dentists with less than 20 years in service, 37% ($p = .04$).

### *Exposure of radiographs*

Dental nurses and dental hygienists exposed 92% of the panoramic radiographs and 75% of the CBCTs. Thirty per cent of clinics with access to a panoramic unit exposed >30 panoramic radiographs per month and 56% of the clinics having access to CBCT did more than 75 examinations per year (>6 per month). More than 30 panoramic examinations were done per month in 80% of the group practices and in 20% of the solo practices ($p = .016$), and in 86% of the PDHS and in 14% in the PP practices ($p < .001$). More than 6 CBCTs were exposed per month in 71% of the group practices and in 29% of the solo practices, and in 85% of the PDHS and in 15% in the PP practices ($p = .008$).

## Discussion

This study focused on the use of extraoral digital radiography, PAN and CBCT. More than half of the Swedish dentists had access to PAN, while fewer than a tenth had access to CBCT. There was a greater likelihood of having access to both PAN and CBCT among dentists who worked in PDHS compared with PPs and among those who worked in a group practice as well as those who had undergone any postgraduate course in oral radiology.

### Methodological discussion

The results of this study are based on a survey of Swedish dentists' use of radiographic techniques with all the weaknesses a questionnaire can have, such as the response rate and the uncertainty in the answers. The results have been supplemented with data from different authorities regarding the numbers of equipment sets and investigations. The questionnaire and the response analyses, including nonresponses, have been previously extensively described. The study included both dentists from the PDHS and PPs. However, slightly more than half of the dentists work within the PDHS. Data from private dental care show that about 45% of Swedish dentists are PPs [22], while data in the previous study showed that 30% are PPs. Thus, there is a discrepancy between official data and data from the study. Whether this difference has affected the outcome of the study, it is not possible to say. Among the PPs, only those dentists affiliated to the SDA were included, due to the opportunity to access email addresses [3].

### Panoramic radiography

Over the past three decades, there has been a significant increase in the number of panoramic instruments in use among Swedish dentists, an increase of 85% from 1984 [23] to today. The increase in the presence of panoramic equipment has resulted in an increase in the number of panorama surveys, with 10% registered by official authorities between 2009 and 2016 [24]. The same observation has been made in a British study where the number of panoramic radiographs taken in general practice has steadily risen in recent years [25]. Around 70% of the panoramic images were exposed to children and adolescents shown in record data from Region Örebro County. A similar observation was disclosed in a 1988 study showing that about 50% were taken on children and adolescents [23]. There are good reasons to assume that a large part of the panoramic images taken on children and adolescents are on orthodontic indications.

In three studies it was shown that around 60% of the dentists had access to a panoramic X-ray device, a British [25] study, a Flemish study [17] and the present study. For two of the studies, the present and the British [25] ones, the figures are comparable, since access to panoramic equipment means that the equipment is shared by a number of dentists in the same clinic. However, in the Flemish study dentists do own the panoramic units in their own practices, and most of the practices are solo practices. Data from the Swedish Dental Association show that there were 7700 dentists in Sweden in 2015 [21], and there were 1300 panoramic units, according to the SSM.

The majority of Swedish dentists work in group practices. To work in a group practice may have significant benefits concerning large investments such as the purchase of panoramic equipment. Dentists working in group practices had two times higher odds of having panoramic equipment compared with those in solo practices. In group practices almost seven out of ten had access to panoramic equipment compared with five out of ten in solo practices. Similarly, a recent study showed that 88% of the panoramic units are in group practices [20]. Panoramic equipment is more often found in PDHS clinics, as dentists working in private practice were 40% less likely to have panoramic equipment.

In the current study, digital panoramic techniques were used in 4/5 of the devices, which accords with a recent publication where 84% of the panoramic devices were equipped with a digital detector [20]. The SSD technique was used by the majority of the responding Swedish dentists, which is more frequent than is observed in other European countries, where an SPP system was chosen over an SSD system by about two-thirds of the dentists [17,26,27]. The difference between Swedish and European dentists regarding the choice of digital technology may be explained by the Swedish dentist possibly preferring a system that delivers the image automatically to the monitor, rather than detouring through a scanner; moreover, a procurement process that favors a solid-state system over the SPP system might lead to it being chosen for that reason [3].

### Cone beam CT

CBCT technology has been a success in dentistry, and interest has literally exploded due to rapid technological progress achieved through better scanners, the development of new sensors and powerful personal computers [6–8].

In connection with the increase in the number of CBCT devices in Sweden, the number of CBCT surveys has increased significantly, more than doubling in 2013–2016, as reported by the Dental and Pharmaceutical Benefits Agency (TLV). While there are no national data on the use of PAN or CBCT on children, regional data showed an increase of 14% in CBCT examinations during 2013–2015 for children and adolescents. About 36% of all CBCT examinations were done on children and adolescents in 2013–2015 (Region Örebro County). The national data refer to adults only, not to children and adolescents, as the TLV does not record information about children and adolescents. However, as the number of X-ray examinations increases, an increase in radiation dose for the CBCT examinations will be found [28], and in conjunction with the increased use of CBCT, an increase in public interest in CBCT technology has led to questions from both patients and practitioners about safe use and best practice [29].

Although the radiation dose is small for an individual, there is still a risk in every X-ray examination, and multiplied by a large number of subjects undergoing X-ray examination, it may constitute a significant public health problem [8]. Major concerns have been raised regarding the indications for use of CBCT because of the radiation doses that patients receive [30]. A medical or dentomaxillofacial radiologist must be responsible for the clinical use of the CBCT unit, including interpretation of the results from the examinations [7]. According to the regulations in Sweden, all CBCT units have to be registered and supervised by a medical physicist responsible for performing quality assurance, including dose measurements [12].

There are a large number of different CBCT brands on the market, where 15 different manufacturers offer a wide range of CBCT models [31]. There are units with supine, sitting and standing patient position. A recent study showed that the standing patient position was the most common, and is often found in hybrid systems, including both a panorama and a CBCT. According to data for 2018 from the SSM, there are 129 CBCT units in use in Sweden, and a large number are hybrid systems. Thus, clinics with a CBCT were almost 20 times more likely to also have a panoramic device, which may mean that many of them are hybrid systems.

### Postgraduate courses

About 60% of the Swedish dentists had not participated in any postgraduate course in oral radiology since being certified to practice [3], although having participated in a radiology course affected the X-ray technique used. Dentists with postgraduate education had 1.7 times higher odds of having access to a panoramic unit and 1.9 times higher odds of having CBCT equipment, compared with those not attending a postgraduate course in oral radiology. In clinics having access to panoramic equipment, it is mandatory for one of the dentists to have passed a licensed PAN course. Fewer than half of the dentists having access to panoramic equipment reported having attended a postgraduate course in oral radiology. Courses in panoramic radiography have been included in the education program at the majority of Swedish dental schools for more than 10 years.

That so few have attended any postgraduate radiology education may be a problem, as there are indications of a large number of dentists carrying out 'routine screening' of their patients without any clinical findings to support such a radiographic examination [18,32]. Routine panoramic X-ray examinations, which are not acceptable, imply increased costs for patients and/or society and may cause a radiation risk to the patient. Positioning errors at panorama examinations are very common, often depending on the ability of the operator, which can lead to varying degrees of diagnostic problems [33–36]. This underlines the need for PAN education and the necessity of developing training programs for optimization of panoramic examinations [17,37,38]. However, there may be an improvement in the operation and knowledge of panoramic radiology in the coming years as more and more dentists are trained in panoramic radiology in connection with their dental training.

There is no mandatory education for Swedish dentists to have or use CBCT. However, the radiological management function for CBCT equipment must be held by a registered dentist with specialist competence in oral radiology. In light of the higher radiation doses using CBCT, it becomes especially important to discuss the role of education. The knowledge gained through continuous education enables a correct assessment, which in turn will reduce the need for CBCT images [39].

Making radiology courses mandatory might have an effect on dentists' approach to handling the equipment, which in turn could lead to X-ray images of a higher quality. Around the world there are differences; some countries have made training mandatory, and some have not. Most countries of the Council of European Dentists (CED), representing dentists in 30 countries in Europe, have compulsory secondary education. In the USA (American Dental Association, ADA) and in Norway (Norwegian Dental Association, NTF) postgraduate education is mandatory. However, mandatory courses have been the case in Belgium for about 10 years, without any improvement being seen [17]. Likely the design of the course has great importance for the outcome: it should include both a theoretical and a practical part, and in addition, knowledge testing to complete the education. When new methods/equipment, like CBCT are introduced, education and training become particularly important to ensure radiation safety for patients and dentists/operators.

### Clinic size

In the present study two-thirds of the dentists worked in group practices. Large dental practices have long been a common clinical form in the PDHS and have become more common also in private dental care. In a recent report from Belgium it was noted that more and more dentists have gone from solo practice to group practice [20]. Working in a group practice may have a number of advantages. First, the cost of major investments can be shared, so that clinics can invest in costly equipment. However, this does not apply to dentists in the PDHS, but only to dentists in private practice. Dentists in the PDHS cannot choose the type of equipment used in their work. The choice of equipment is centrally determined by the management of public dental health services in the county. Second, the possibility of exchanging ideas with colleagues and discussing problems must not be underestimated, as social contacts with colleagues can have a positive influence [40].

### Who makes the exposures?

In the present study, nearly all panoramic and 3/4 of CBCT examinations were made by a dental nurse/dental hygienist, while in Norway oral radiologists, radiographers and specially trained dentists are allowed to perform the actual CBCT scans [7]. In Sweden, an oral radiologist must be responsible for the clinical use of the CBCT, including interpretation of the results from the surveys, but there are no restrictions on the category of operator performing the survey. Belgian dentists are in contrast obligated to do all radiographic examinations themselves, which is in strong contrast to other countries [17]. A US study showed that almost half of the population lives in areas where there are no rules prohibiting untrained staff from either making decisions about X-ray examinations or performing them [41].

### How many exposures?

Around one-third of the Swedish dental clinics exposed more than 30 panoramic radiographs, and just over half exposed more than 75 CBCTs per year (>6 per month). This

is consistent with a study from Norway, which showed that about 7 out of 10 of the clinics had performed on average 4 or fewer CBCT surveys per week [4]. It has been assumed that in the future there will be higher radiation doses in dental imaging because of the increased use of CBCT and digital imaging [28]. With the increased number of CBCT surveys, concern has been expressed for the increased radiation dose given to children and adolescents [12,29].

### *Doses*

There will be higher doses in dental imaging due to increasing use of CBCT and digital imaging. The staff performing dental imaging must have competence in dental imaging quality assurance issues found in this review. When selecting a CBCT examination for an individual, it is important to minimize X-ray dose while striving for an image that enables appropriate diagnosis and management. This requires an understanding of the concepts behind the CBCT and related technologies, making appropriate training essential for every member of the dental team [42].

However, while the effective dose from a CBCT examination is relatively low, it is many times higher than for panoramic imaging [43]. Even if the radiation dose from dental radiology is low, a child may undergo many repeated procedures during childhood and adolescence [28]. Therefore, the accumulated effect of radiation exposure should be taken into consideration. The salivary and the thyroid glands are among the organs at risk in dental radiology [28]. Kadesjö et al. showed that the effective dose from one CBCT examination of an impacted canine was much higher than an intraoral examination comprising two periapical radiographs [44].

Many of the examinations are performed on non-individual indications, as observed in a recent study showing that more years in service decreases the likelihood of applying individual indications [3]. Moreover, studies indicate that routine screening is quite common in patients without any clinical findings to support a radiographic examination [18,32]. It has been estimated that the use of CBCT imaging in dental offices has doubled in the last 20 years. With this increase in usage, radiation exposure to the patient has also increased. The increase in radiation requires the dental practitioner to adhere to ALADA, the principle of 'as low as diagnostically acceptable'. In this concept, the dentist only takes radiographs required to diagnose a potential problem [45].

Indications for the use of digital technologies in oral radiology will be described in a forthcoming study that will cover both intraoral and extraoral techniques.

## Conclusions

This study showed that a majority of Swedish dentists responding to the questionnaire had access to a panoramic unit, and just less than 10% had access to a CBCT unit. Postgraduate education had an effect on the use of extraoral radiography. Dentists working in group practices were more likely to have a panoramic unit than dentists in solo practices, and dentists working in private practice were 40% less likely to have panoramic equipment compared with dentists working at the PDHS. An observation must be that all images should be taken from an individual indication, especially considering the higher radiation that the CBCT implies.

## Acknowledgements

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## Disclosure statement

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