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ORIGINAL ARTICLE

How do dentists use CBCT in dental clinics? A Norwegian nationwide survey

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Abstract

Objectives. Cone beam computed tomography (CBCT) was introduced to Norwegian dental clinics in 2007. The aim of the study was to investigate how dental clinics use this imaging modality, including factors related to workflow and image quality, and to evaluate dentists' opinions on and experiences of using it. ***Materials and methods.*** A web-based 59-item questionnaire regarding the clinical use of CBCT was sent to all 39 CBCT clinics in Norway. ***Results.*** Twenty-nine clinics (74%) responded. Most respondents (93%) were from clinics with more than one dentist and 83% had at least one specialist. All clinics had digital intraoral x-ray receptors and all but one had panoramic imaging. The most common indications for CBCT were implant treatment planning (34% of all clinics) and localization of impacted teeth (43% of specialist clinics). Seventy-two per cent of clinics reported an average of four or fewer CBCT examinations each week and 83% of respondents were subjectively satisfied with the image quality. The most commonly used enhancement functions were contrast (97%), brightness (90%) and zoom (86%). ***Conclusions.*** The Norwegian CBCT clinics surveyed were fully digitized and had multiple dentists. Periodontists and oral and maxillofacial surgeons were the most frequent specialties represented in the clinics. Clinics with only dental specialists performed more CBCT examinations/week than clinics with general practitioners or both general practitioners and specialists. The most common indications for CBCT examinations were related to treatment planning. This study found some challenges related to image quality and communication within the radiological team.

Key Words: *cone beam computed tomography, dental imaging, image quality, survey*

Introduction

Dental cone beam computed tomography (CBCT) was introduced into dental radiography in 1997 [1] and has been used in Norwegian dental clinics since 2007. 2D-imaging, such as intra-oral and panoramic radiography, was the radiographic techniques previously available for dental care. Studies [2–7] have shown that dental CBCT produces 3D images of the dentition and facial skeleton with an acceptable to high degree of accuracy with regard to linear measurement. Only a few studies [8,9] have shown impact on patient treatment planning when adding CBCT imaging to traditional 2D imaging. Even so, the new CBCT technique has quickly become popular with dentists in Scandinavia and worldwide.

The market offers many CBCT machines with various functional hardware designs, scan volumes (fields of view) and other technical parameters that affect radiation and image quality [10–14].

A multi-national research project, SEDENTEXCT, supported by the Seventh Framework Programme of the European Atomic Energy Community (Euratom), was set up to produce evidence-based guidelines for the use of CBCT between 2008–2011. SEDENTEXCT published these guidelines in 2012 [1], but national regulations and guidelines still differ, either because countries have not yet

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aligned with the new guidelines or because they are not members of the EU. In Norway, the National Radiation Protection Authority (NRPA) published guidelines for the use of CBCT in dental practices in 2010, available at www.nrpa.no (in Norwegian). According to these guidelines, all CBCT clinics in Norway must engage a medical physicist responsible for performing quality assurance (QA) for the CBCT unit and a maxillofacial or medical radiologist responsible for clinical use of CBCT and interpretation of examination results. When using scan volumes of 8 × 8 cm or smaller and imaging the dentoalveolar region, the radiologist may delegate CBCT interpretation to another dentist with relevant and documented competence.

Because CBCT is a new type of imaging, it is important to understand and evaluate how CBCT is used in order to determine the best imaging procedures to ensure high-quality images. To our knowledge, no previous studies have investigated how and why CBCT is used in dental clinics. Thus, the aim of the study was to investigate the use of CBCT in Norwegian dental clinics, including factors related to CBCT workflow and image quality in clinical practice and to evaluate dentists' opinions on and experiences of using CBCT.

Materials and methods

In December 2012, we sent a web-based questionnaire (QuestBackNorge, Løvenskiolds gate 26, 0260 Oslo, Norway) to all 39 CBCT clinics registered nationally with the NRPA. The questionnaire was addressed to the radiation protection officer (the person responsible for radiation protection and safety) at each clinic. The cover letter informed respondents that their answers would be treated anonymously. All the researchers signed the cover letter and could be contacted in case of questions or remarks about the questionnaire. We also sent four reminders about the survey, the last two by post.

The questionnaire comprised 59 questions. The first section of the questionnaire gathered subject characteristics of the respondents such as gender, age and education. The second section concerned the clinic and its radiographic equipment, with emphasis on CBCT. The third section included items on CBCT workflow and image quality. The fourth section queried technical aspects of equipment installation and other vendor-related issues. Finally, the respondents were asked to comment on their experiences with CBCT. The full questionnaire can be obtained from the corresponding author.

Results

Twenty-nine (74%) of the 39 clinics responded to the questionnaire. The respondents were almost exclusively dentists and male (both 97%) and 66% were aged 45 or older (range = 27–64 years).

Most of the respondents (93%) worked in clinics with more than one dentist and 83% of the clinics had at least one dental specialist in addition to a radiologist. Excluding the radiologists, in 17% of the clinics, all the dentists were general practitioners (general clinics). In 24% of the clinics, all the dentists were specialists (specialist clinics). The remaining 59% of the clinics had a combination of general dental practitioners and specialists (combination clinics). Table I shows the distribution of the different specialties in the CBCT clinics.

In addition to CBCT, all clinics had digital intraoral x-ray receptors. All but one clinic had panoramic x-ray units and all of these were digital. The CBCT machines came from seven different manufacturers, representing 12 different trade names.

Indications

In all clinics, the most common use of CBCT was related to planning implant treatment (34%). In specialist clinics, however, the most common use was related to locating impacted teeth (43%). Seventy-two per cent of clinics performed an average of four or fewer CBCT examinations per week (range = 0–10). However, 86% of the specialist clinics performed an

Table I. Distribution of dental specialties represented in the Norwegian CBCT clinics.

Specialties[a]	All clinics, n^c (%)	Specialist clinics, n^c (%)*	Combination clinics, n^c (%)**
Endodontics	10 (34)	2 (29)	8 (47)
Oral and maxillofacial surgery	12 (41)	4 (57)	8 (47)
Orthodontics	7 (24)	1 (14)	6 (35)
Pedodontics	1 (3)	—	1 (6)
Periodontics	16 (55)	3 (43)	13 (76)
Prosthodontics	9 (31)	3 (43)	6 (35)

[a]Norwegian specialty titles. Maxillofacial radiology excluded.
n^c,number of clinics, 29, 7 and 17, respectively.
*Specialist clinics = clinics with only dental specialists.
**Combination clinics = clinics with both general practitioners and dental specialists.

Table II. Patient positioning, support devices and scout function used by the CBCT clinics.

Imaging process	Percentage
Patient standing	69%
Patient sitting	31%
Patient supine	0%
>3 head support devices, overall	83%
Chin support	90%
Temporal support	62%
Forehead band	59%
Frontal head support	55%
Scout image available	69%
Regular use of scout image when available	75%

average of five-to-ten examinations per week (range = 1–10).

CBCT scanning

In 86% of the clinics, one person—usually a dentist—performed all CBCT scans. This was evenly distributed between general dental practitioners and specialists. There were variations between the clinics in patient positioning procedures and the head support devices used. More than two-thirds of the machines had a scout image function and 75% of the clinics with scout image function available used it regularly (Table II).

Image quality

Anatomical structures reported to be clearly detectable in CBCT clinics are presented in Table III. The responses showed that 72% of respondents were able to clearly detect all four anatomical structures and 57% of specialist clinic respondents were able to detect all four. Overall, however, the respondents were 'satisfied' or 'very satisfied' (83%) with the image quality. All clinics reported routine use of at least one image enhancement function when evaluating the images, with 72% of respondents using three to five different enhancement functions (range = 1–8 functions). The most commonly used functions were contrast, brightness and zoom (Table IV). The least-used enhancement function categories were coloring and other imaging functions. The questionnaire instructed respondents to 'mark a maximum of two of the most common image artifacts in your clinic'. Only 62% of respondents answered this question as instructed. Thirty-eight per cent of respondents reported more artifacts than the two they most commonly found. Among the 18 clinics that responded as instructed, the most commonly detected image artifacts were related to metal tooth restorations (89%). Other commonly reported artifacts included titanium artifacts, i.e. artifacts in relation to implants (33%) and artifacts presenting as a narrow black space/line around root canal fillings or titanium implants (28%). Patient movement artifacts that were seen as blurry bone structures/false bone discontinuity/double bone or tooth contours in CBCT images were reported as one of the two most common artifacts by 22% of respondents. Dentists in two clinics seldom detected any artifacts.

Table IV. Image enhancement functions used regularly while analyzing CBCT images.

	All clinics (%)
Contrast	97
Brightness	90
Zoom	86
Histogram equalization	45
Edge enhancement	38
Inversion	28
Coloring	24
Other image enhancement functions	24

Interpretation and use of images

A large majority of respondents (72%) usually interpreted the CBCT results before receiving the radiological report. All the specialist clinics reported evaluating the images prior to the radiological report. Excluding two clinics who did not respond to this item, all respondents read the reports. Of those who responded, 78% both read the reports and viewed the

Table III. Anatomical structures reported to be clearly detectable in CBCT clinics.

	All clinics (%)	Specialist clinics* (%)	Combination and general clinics** (%)
Trabecular bone pattern	97	86	100
Mandibular canal	97	86	100
Marginal cortex (edentuluous areas)	86	86	95
Periodontal ligament space	83	71	86

*Specialist clinics = clinics with only dental specialists.
**Combination clinics = clinics with both general practitioners and dental specialists. General clinics = clinics with only general dental practitioners.

images, while 22% only read the reports. When queried about treatment start, 52% of clinics reported waiting to start patient treatment until receiving the radiological report, while 38% usually started treatment before receiving the report (10% did not respond). In specialist clinics, 71% started patient treatment prior to receiving the radiological report. Reported reasons for starting treatment before receiving the report included acute situations and situations in which diagnosis and treatment could be completed in one visit. Some respondents reported that they felt competent to interpret the images themselves for specific clinical problems. In some clinics, the time between performing the examination and receiving the radiological report was considered to be too long.

Most respondents (83%) reported showing the images to patients to illustrate the diagnosis or treatment plan.

Backup

Almost all clinics (97%) regularly made backup copies of their CBCT examinations, 86% on a daily basis.

Comments/experiences

The most commonly reported advantage to having a CBCT unit in the clinic was improved diagnostics and treatment planning. Respondents also mentioned greater patient safety due to improvements in treatment predictability and procedures and to reductions in post-treatment complications. Other reported advantages included time savings because patients did not need to be referred to another clinic and lower radiation doses because the field of view could be collimated to the exact region of interest.

The most commonly reported challenges of having a CBCT in the clinic were the time and money required to operate it. Time-consuming aspects of CBCT included administrative tasks, mandatory presence during scans and communication with the radiologist. The high costs reported for CBCT arose from the need to engage a radiologist and medical physicist. A few respondents reported that their greatest challenges were developing competence in the procedures and learning to use the equipment and interpret the images correctly. Respondents were also concerned with the frequent updates and long installation times associated with CBCT machines.

Overall, the respondents praised the CBCT technique for its usefulness in diagnostics and treatment planning.

Discussion

This study included all registered CBCT clinics in Norway (n = 39). Our response rate of 74% is comparable to other similar questionnaire studies [15–18]. The non-respondents included six private clinics and all hospital and dental university clinics. This study can, thus, be considered representative of dental care clinics providing either general care or specialist care.

The clinics were fully digitized with respect to x-ray imaging units. One clinic did not have a panoramic x-ray unit. Even though panoramic examinations are often used prior to CBCT examinations, panoramic x-ray units are not mandatory in Norwegian CBCT clinics.

Considering the costs of CBCT equipment, we were not surprised that a large majority of the clinics provided specialist care. Norway has seven recognized dental specialties, all of which were represented in one or more of the responding clinics. Our study, thus, indicates that CBCT in Norway to a large degree is used in patient situations demanding specialist care.

Indications

The most common indications for CBCT examinations in our study were implant treatment planning and location of impacted teeth. A recent study [9] showed that implant planning using panoramic imaging was leading towards the use of longer implants in posterior locations than when CBCT images were used. CBCT images were found to be equal or superior to conventional 2D images of impacted canines with respect to the canine's position in the arc [6,19]. For detection of the relationship of the mandibular canal to the third molar, it has been shown that 12% of treatment plans were changed when 3D images were compared with 2D images [20]. Another study concluded that CBCT had a significant impact on therapeutic decision efficacy in endodontics when used in concordance with the current European Commission guidelines [8]. However, some studies concluded that there was no significant difference in treatment plans with CBCT images. One review [21] concluded that no evidence in the literature was found to support any specific imaging modality when planning dental implant placement in any region of the mouth. Another study [22] found no significant difference between panoramic and CBCT images in surgical treatment planning of impacted maxillary canines.

Our study revealed fewer weekly CBCT examinations than expected, but we found no previous studies with which we could make comparisons, despite general concern internationally about inappropriate levels of use [1,23]. Despite the fact that the CBCT technique is new, it was surprising that dentists did not perform CBCT on more patients. The complex regulations in Norway, including the requirement of having an affiliated radiologist, may partly explain the low number of examinations. Other potential explanations include a general lack of knowledge among dentists about referral criteria and justification

and a lack of referral habits between private dental practices for this type of examination. However, it should be considered that the actual number of CBCT scans made may be higher than reported. There is a risk with questionnaire studies that respondents answer questions as they feel they should be answered. In this study, one can assume that respondents felt it correct to keep the number of CBCT scans reported to a minimum on account of radiation doses to patients.

CBCT scanning and image quality

The study found that ~50% of all CBCT examinations were performed without scout imaging, mainly because the machines lacked this function. The scout function is always used in medical CT imaging and clinical experience indicates that CBCT scout imaging may reduce the need for retakes. Since the questionnaire did not include questions on retakes, this would be interesting to investigate further.

All respondents reported artifacts related to metal tooth restorations. Many also reported artifacts related to other high-attenuating materials. These findings are consistent with known CBCT image artifacts [24] and show the need for further technological development. Movement artifacts in CBCT images were common, with 22% mentioning this as one of the two most common artifacts in their clinic. More than two-thirds of the clinics in the present study had CBCT systems that use standing patient positioning. Eighty-three per cent of respondents used three or more head fixation devices. The remaining respondents (17%) used one or two support devices, which may indicate less than sufficient head fixation for this group. A previous study [25] reported that any head motion resulted in artifacts in CBCT images. The severity of the artifacts resulted in different effects on the image quality dependent on the region and level in the skull. In order to limit movement artifacts, a recommendation would include sufficient fixation of the patient's head during scanning and increased speed of the detector readout for shorter scan times [24]. Donaldson et al. [26] showed that almost none of the CBCT images evaluated in their study had to be retaken due to movement artifacts.

Even though the majority of respondents were able to detect all the anatomical structures mentioned in the questionnaire (Table III), the images at many clinics did not provide adequate information. The differences between clinics in detecting the anatomical structures may be due to inferior image quality, image artifacts, differences in use of image enhancement functions or differences in examiner experience and interpretation of 3D images. In the present study on 3D imaging, contrast and brightness were the most commonly used image enhancement functions, which is consistent with studies on 2D dental imaging [16,18,27]. In the questionnaire, contrast and brightness were addressed separately. The terms are familiar in the dental community using 2D digital radiography and some CBCT software use the functions separately, although in other CBCT software the functions are presented as one combined 'windowing function'. In the windowing function, contrast and brightness can be adjusted separately or in combination.

Interpretation and use of images

Seventy-two per cent of respondents interpreted the images themselves and 38% usually started treatment before receiving the radiological report. The reasons for starting treatment differed. Surprisingly, none of the respondents reported that the radiologist had delegated the task of interpretation to them, even though this is an option in Norway.

In this study, the CBCT examinations were commonly used to illustrate the diagnosis and/or treatment plan to the patients, which is consistent with clinical experience using digital 2D imaging.

Comments/experiences

The vast majority of respondents were satisfied with the CBCT technique. The respondents experienced subjective improvement in diagnostics, treatment planning and evaluation of prognosis, with fewer treatment complications. These positive experiences are not supported by much evidence from previous studies, although this may be due to the sparse number of studies with high levels of evidence and of studies on patient outcomes [1].

The respondents also believed that the use of CBCT was time-consuming and costly. The costs mentioned by the respondents were directly associated with the need of additional (affiliated) personnel, not the additional costs to the patients and society as a few studies have addressed [28–30]. Christell et al. [28] analyzed the costs in Sweden for radiographic examinations of maxillary canines with eruption disturbances, comparing intra-oral and panoramic radiography with panoramic radiography and CBCT examination. From their data it can be concluded that the costs for the latter examinations were ~1.6-times the costs of the former, conventional examinations. In a Danish study, Petersen et al. [29] compared the costs for panoramic radiography with CBCT examination for pre-operative diagnostic evaluation of impacted mandibular third molars and found that the CBCT examinations were 3–4-times the costs for panoramic radiography. However, another study by Christell et al. [30] found that both direct and indirect costs regarding CBCT varied and concluded that a cost evaluation could not be generalized between different healthcare systems.

Communicating with the radiologist and medical physicist was mentioned as a challenge. Some believed that the biggest challenge was learning how to use the technique and interpret the images. The European Academy of DentoMaxilloFacial Radiology recognizes this need for continuing education and suggests a curriculum for CBCT training [31].

Conclusion

The Norwegian CBCT clinics surveyed were fully digitized clinics with multiple dentists and usually at least one specialist in addition to a radiologist. Periodontists and oral and maxillofacial surgeons were the most frequent specialties represented in the CBCT clinics. The most common indications for CBCT examinations were implant treatment planning and localization of impacted teeth. Clinics with only dental specialists performed more CBCT examinations per week than clinics with only general practitioners or both general practitioners and specialists. Even though the respondents were subjectively very satisfied or satisfied with the CBCT image quality, more than 1/4 of the respondents did not generally clearly detect all the four anatomical structures—the mandibular canal, trabecular bone pattern, marginal cortex and periodontal ligament space—in the CBCT images. We found some challenges related to image quality and communication within the radiological team concerning the radiological report.

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