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Ich bedanke mich bei den unten aufgeführten Kolleginnen und Kollegen für ihre wertvolle Mitarbeit, die sie in den vergangenen drei Jahren geleistet haben.

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SADMFR Guidelines for the Use of Cone-Beam Computed Tomography/Digital Volume Tomography

Endodontics, Periodontology, Reconstructive Dentistry, Pediatric Dentistry

A consensus workshop organized by the Swiss Association of Dentomaxillofacial Radiology

KEYWORDS
cone-beam computed tomography,
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SUMMARY

In 2011, the first consensus conference on guidelines for the use of cone-beam computed tomography (CBCT) was convened by the Swiss Society of Dentomaxillofacial Radiology (SGDMFR). This conference covered topics of oral and maxillofacial surgery, temporomandibular joint dysfunctions and disorders, and orthodontics. In 2014, a second consensus conference was convened on guidelines for the use of CBCT in endodontics, periodontology, reconstructive dentistry and pediatric dentistry. The guidelines are intended for all dentists in order to facilitate the decision as to when the use of CBCT is justified.

As a rule, the use of CBCT is considered restrictive, since radiation protection reasons do not allow its routine use. CBCT should therefore be reserved for complex cases where its application can be expected to provide further information that is relevant to the choice of therapy.

In periodontology, sufficient information is usually available from clinical examination and periapical radiographs; in endodontics alternative methods can often be used instead of CBCT; and for implant patients undergoing reconstructive dentistry, CT is of interest for the workflow from implant planning to the superstructure. For pediatric dentistry no application of CBCT is seen for caries diagnosis.

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Introduction

In 2011, the first consensus conference of the Swiss Association of Dentomaxillofacial Radiology (SADMFR) was held on the use of cone-beam computed tomography (CBCT) in oral and maxillofacial surgery, temporomandibular joint disorders, and orthodontics (Dula et al. 2014). Since CBCT is increasingly being used for diagnosis in endodontology, periodontology, reconstructive dentistry, and pediatric dentistry, a second consensus conference was convened in 2014 to develop guidelines in these fields. The discussion of the disciplines resulted in guidelines designed to offer general perspectives on the potential benefit to patients through the use of CBCT imaging. The guidelines address general aspects as well as situations encountered in daily practice and should be followed whenever possible. However, in special circumstances a different approach may be required to resolve individual cases. The SADMFR emphasizes that under these circumstances a thorough medical history, the clinical examination and two-dimensional radiography remain the three pillars of today's practice. It is only with sound knowledge acquired through continuous education that the information from these three pillars can be properly assessed. This in turn will considerably reduce the need for CBCT images.

As a basic principle, all CBCT imaging has to be indicated by the professional treatment of the patient. If the decision is made to refer a patient to a colleague or specialist, no further imaging should be performed. Even if it is consistent with these guidelines, unnecessary exposure can be avoided, because the decision on special imaging should be made by the responsible person or specialist.

In most cases the region of interest is small and therefore only a small field of view should be applied. The decision regarding the spatial resolution must be based on the specific situation as endodontology, for example, generally requires high-resolution imaging whereas most decisions in implantology can be made based on low-resolution imaging (and thus a lower radiation dose). Kilovoltage (kV) and milliampere (mA) settings have to be chosen according to the particular indication.

Material and Methods

On January 13 and 14, 2014, the SADMFR convened for its second consensus workshop to establish indications and contraindications for CBCT in the above-mentioned disciplines of dental medicine.

For the second consensus workshop a core group of twelve members was appointed according to strict selection criteria. They had to have expert knowledge in their field of work gained through extensive personal experience, they had to be highly skilled, their expertise had to be generally recognized and they had to have worked intensively for several years with CBCT. All had to be dentists and all had a doctor's degree as well as one or more specialty degrees. The core group thus included two periodontists, two endodontists, three specialists in reconstructive dentistry, five oral surgeons, and one maxillofacial surgeon (one participant with two specialist titles). For some specialties, a specialist title is not currently available in Switzerland. It should therefore be noted that three members of this group are also working primarily as dentomaxillofacial radiologists. At the time of the consensus conference all twelve participants were working in one of Switzerland's universities, six of the twelve as chair or head of a department, division or section, and six were full professors or associate professors, scientific associates or senior lecturers.

The workshop was organized with a rigid timetable from 9:00 a.m. to 6:30 p.m. on January 13, 2014 and from 8:00 a.m. to 3:30 p.m. on January 14, 2014. Before the meeting, all experts had to prepare a position paper on the use of CBCT in their respective working field. This document served as a basis for discussion for the whole group, which proceeded according to the points on the agenda. The agenda had been set up by the organizer of the consensus conference who subsequently chaired the group.

Each group presented its proposals, which were then discussed and adopted by consensus in plenary. The outcome was the SADMFR guidelines for the use of CBCT with the main authors of each chapter given in parentheses.

The consensus statements in this paper are based whenever possible on the current literature, including systematic reviews and clinical trials. Where these sources are unavailable, consensus statements are based on expert opinion and consensus of the group following plenary discussion.

Results

Application of CBCT in periodontology (A. Sculean and C. Walter)

Periodontal diagnosis is generally based on medical and periodontal history, indicators of inflammation, probing pocket depth, probing attachment level, probing of the furcation entrance, and periapical radiographs (Walter et al. 2013). To select the appropriate periodontal treatment option, a thorough diagnosis is required. This comprises, in particular, the characterization of the anatomy/morphology of the vertical defect, the degree of horizontal and vertical furcation involvement, the assessment of the residual inter- and periradicular bone, and the evaluation of root morphology. Accurate analysis of the defect morphology with conventional clinical and radiographical tools is difficult owing to limited access, morphological variations, and measurement errors (Eickholz 1995, Eickholz & Hausmann 2002, Walter et al. 2011). Three-dimensional imaging using CBCT can facilitate diagnostic accuracy in specific cases as described in the guidelines.

The literature on CBCT for periodontal diagnosis, treatment planning, treatment outcomes, and/or its benefit for the patient is scarce. Six publications, identified from a systematic literature search (accessed 20 June 2014), describe relevant data for this consensus statement (Walter et al. 2009, Grimard et al. 2009, Walter et al. 2010, de Faria Vasconcelos 2012, Walter et al. 2012, Qiao et al. 2014). Four of these publications refer to maxillary molars and two to aspects related to vertical bony defects.

The evidence for the use of CBCT as a standard radiological tool for periodontal diagnosis is lacking. Two available studies on this subject demonstrate a high accuracy of CBCT in detecting intrabony defect morphology when compared to periapical radiographs (de Faria Vasconcelos et al. 2012, Grimard et al. 2009). However, neither the relevance of CBCT in the treatment decision-making process nor its benefit for the patient has yet been assessed.

Data from two different populations have shown a high accuracy of CBCT imaging for the analysis of the morphology of maxillary molars and surrounding periodontal tissues (Walter et al. 2009, Walter et al. 2010, Qiao et al. 2014). In addition, CBCT enabled the estimation of periapical lesions, combined periodontal-endodontic lesions, the assessment of existing root canal treatment, the appraisal of the second mesiobuccal root canal, or the inflammatory status of the Schneiderian membrane (Dagassan-

Berndt et al. 2013, Walter et al. 2011). A case series showed a discrepancy in treatment recommendations for the majority of maxillary molars with the treatment decisions based on clinical data and periapical radiographs compared to those obtained by CBCT. The CBCT enabled more precise planning of surgical treatment by facilitating the decision about resective surgical interventions with a specification of the roots planned to be preserved (Walter et al. 2009). A preliminary analysis revealed a possible reduction of treatment time and costs (Swiss dentist tariff) for periodontally diseased maxillary molars when CBCT was used (Walter et al. 2012). When more invasive treatment approaches were considered, the use of CBCT demonstrated advantages in decision-making on tooth extraction versus preservation.

Conclusions:
- A series of periapical radiographs meets the standard of care for pre- and post-treatment radiographic assessment and follow-up.
- CBCT provides high accuracy in detecting the morphology of vertical bony defects. However, for the reasons outlined above, its routine use for assessing intrabony defects is not recommended.
- In maxillary molars, CBCT provides high accuracy for detecting furcation involvement and morphology of surrounding periodontal tissues. CBCT has demonstrated advantages when more invasive treatment approaches are considered, and can thus aid complex treatment planning.

Application of CBCT in endodontics (F. B. Kissling-Jeger, M. Zehnder, P. Sequeira-Byron, M. M. Bornstein)

Basic considerations

Existing guidelines were scrutinized when preparing for this report (Barbakow & Velvart 2005, American Association of Endodontists & American Academy of Oral and Maxillofacial Radiology 2011, Jeger et al. 2013, Schulze et al. 2013). In addition, the authors considered a recent systematic review in which the diagnostic accuracy of radiographic methods used to indicate the presence or absence of periapical lesions, or changes to such lesions over time, was evaluated (Petersson et al. 2012). It should be reiterated that the main focus of the current guidelines is on the risk-benefit ratio for the patient. Established case difficulty assessment protocols were used to support the decision-making process in this context (Morand 1992, Simon 1999, Ree et al. 2003). These protocols categorize cases according to three levels of difficulty: minimal, moderate and high. As explained below, most of the indications to use CBCT imaging fall into the high difficulty category. The diagnostic standard remains the single-tooth X-ray, which may be supported by a second angulation (Brynolf 1970a, Brynolf 1970b, Brynolf 1970c, Brynolf 1970d) or other diagnostic measures. In view of the high radiation dose from three-dimensional imaging compared with that associated with periapical images, this option should always be considered first. The dental microscope has revolutionized endodontic treatment and decision-making and, in many cases, a dental microscope makes CBCT imaging redundant. If CBCT is performed for single-tooth assessment, a small field of view and high resolution must be selected (Scarfe et al. 2009).

The two main domains that should be considered in endodontics are surveillance of periapical tissues over time and peri-treatment decision-making, as discussed below.

Surveillance of periapical tissues

The two most important issues in periapical diagnostics are the correlation between radiological appearance of a lesion and its histological features, and the changes of this appearance in the context of healing or aggravation of the inflammatory process. Both these issues have been studied in detail using two-dimensional imaging (Brynolf 1970a, Brynolf 1970b, Brynolf 1970c, Brynolf 1970d, Ørstavik 1996). Ørstavik's landmark study made it clear that teeth should be radiographically controlled one year after endodontic treatment. The absence of a new lesion or the reduction of a pre-existing counterpart indicates healing. Up to now, these important issues have not been studied using current three-dimensional imaging. While CBCT images show more periapical lesions than single-tooth X-rays (Lofthag-Hansen et al. 2007), we do not know what these lesions signify in terms of health and disease. A recent follow-up study compared the appearance of the periapex in endodontically treated teeth using conventional single-tooth X-rays and using CBCT. The results showed that there was no apparent difference between CBCT and periapical radiographs when it came to the enlargement of pre-existing lesions, indicating treatment failure. On the other hand, there were 14 times more (small) apical lesions visible on CBCT images than on periapical radiographs of teeth with no lesions prior to treatment. These lesions, as mentioned by the authors, could reflect transient changes in periapical hard tissues.

In summary, there is no current evidence that monitoring of periapical tissues should be performed using CBCT as a matter of routine.

Peri-treatment decisions

The high detection rate of hard tissue changes in CBCT scans can be helpful in the diagnostic process. On the other hand, this could also lead to overtreatment, as discussed below. The patients' welfare should not be forgotten. It is mandatory to enquire whether CBCT imaging has been performed previously. This could then be used, for example, for initial length measurement (Jeger et al. 2013).

Root anatomy

In teeth with atypical anatomy, which could potentially impact endodontic treatment, a CBCT scan may be considered. These conditions include radix ento- and paramolaris (Abella et al. 2011), dens invaginatus, and palatal grooves (Michetti et al. 2010). It has been repeatedly shown that low-volume, high-resolution CBCT is superior to two-dimensional imaging in managing these cases (Patel et al. 2009).

It has also been shown that using high-resolution CBCT, normal structures such as second mesiobuccal (mb2) canals in maxillary first and second molars can be identified (Blattner et al. 2010). However, endodontists expect and search for mb2 as a matter of course; a task made easier with a microscope. Hence the utility of CBCT in identifying mb2, or any other root canal anatomies that are generally expected, is limited.

Radiolucencies mimicking apical lesions

Lesions of nonendodontic origin can develop around a tooth's periapical region, and if not diagnosed early and correctly they can expand to become large lesions. In the case of a nasopalatal duct cyst (NPDC; Suter et al. 2011a) or Stafne's bone cavity (SBC, also known as static bone cavity, latent bone cavity, idiopathic bone cavity, lingual mandibular bone concavity, or lingual mandibular bone depression), findings of a radiolucent structure in two-dimensional intra- or extraoral radiographs can pose a true diagnostic challenge (Bornstein et al. 2009a). These lesions may mimic apical periodontitis or a radicular or residual cyst, which often leads to incorrect and unnecessary treatment such as root canal treatment, bone trepanation or surgical exploration (Katz et al. 2001, de Courten et al. 2002).

NPDCs are diagnosed incidentally on apical or occlusal radiographs during routine examinations. In most cases, the anterior teeth react positively to pulp sensitivity testing (Suter et al. 2011a). Correct diagnosis is more difficult when pulp sensitivity testing is negative or when endodontic treatment has already been performed in the incisor region. When NPDCs are misdiagnosed as periapical lesions, inappropriate endodontic treatments may be initiated (Terry & Bolanos 1989, Gnanasekhar et al. 1995, Faitaroni et al. 2011). On CBCT scans of the anterior maxilla, periapical radiolucencies can be differentiated from NPDCs in the initial stages, usually showing a characteristic bulky enlargement of the nasopalatine canal (Suter et al. 2011b).

SBCs are mostly seen in the pre-angular region of the mandible below the mandibular canal. When SBCs occur in the more anterior part of the mandible in close contact with tooth roots, they can mimic periapical lesions of endodontic or non-endodontic origin (Anneroth et al. 1990, Barak et al. 1993, Katz et al. 2001). In some cases, the more anteriorly located SBC variant can mimic a residual cyst when it occurs in an edentulous area of the mandible (de Courten et al. 2002). The differential diagnosis of anterior SBCs should include solitary (traumatic) bone cyst, lateral periodontal cyst, and early stage focal cemento-osseous dysplasia (Thomas & Abramovitch 1996). In general, the periodontal ligament, which can be well identified in CBCT images, is one of the leading structures in radiographs identifying a lesion as being of odontogenic or non-odontogenic origin.

Vertical root fractures

Because of the relatively low resolution of CBCT, vertical root fractures cannot be identified directly unless they exceed a threshold value of 50 µm (Brady et al. 2013). However, the bone lesion that typically delineates the fracture line can more easily be followed on three-dimensional images than two-dimensional ones (Bornstein et al. 2009b). This is because these fracture lines are typically found in a bucco-oral plane (Lustig et al. 2000). In this context, however, it should be reiterated that other diagnostic measures that do not expose patients to radiation can be just as helpful in the diagnostic process. These are periodontal probing and, with the highest degree of clinical certainty, explorative surgery. Therefore, CBCT can be avoided. Evidence-based data as to what are the best tools for non-invasive identification of vertical root fractures are elusive (Tsesis et al. 2010).

Cervically-invasive root resorptions

Root resorptions in general are discussed in Part I of this consensus report. One form of resorption stands out in the context of endodontic treatment decision-making, and that is the so-called cervically-invasive root resorption (CIRR, Heithersay 1999a). Three-dimensional imaging can provide important information regarding the location and extent of CIRR (Patel 2009). This information is required to decide whether a tooth needs to be extracted, or whether the resorptive process can be managed from the periodontal or the endodontic aspect (Heithersay 1999b). Thus, high-resolution CBCT is justified in cases of suspected CIRR.

Chronic pain

In the context of chronic pain related to a root canal-treated tooth, CBCT imaging has been suggested as a diagnostic measure (Pigg 2011). CBCT can be useful to identify a relationship between an apical process and highly innervated tissues such as the periosteum (Pasqualini et al. 2012). However, it should be understood that persistent idiopathic facial pain (formerly known as "atypical facial pain") is often the underlying cause of subjectively experienced, persistent odontalgia (Polycarpou et al. 2005). Hence, CBCT can be useful to exclude a periapical inflammatory process in the context of chronic pain (Pigg 2011). On the other hand, clinical experience also shows that, even if an apical lesion is identified on a tooth associated with chronic pain, endodontic (re)treatment very rarely relieves the patient's symptoms (Remick et al. 1983).

Sinus involvement

Three-dimensional imaging has revealed that periapical lesions in maxillary lateral teeth are often associated with apparent inflammatory changes in the sinus (Bornstein et al. 2012). Proper endodontic treatment can result in the remission of unilateral maxillary sinus disease (Pokorny & Tataryn 2013). For the identification of sinus disease, some form of three-dimensional imaging often already exists. Hence, for the endodontic treatment per se, no additional CBCT is indicated. Instead, the normal documentation using single-tooth X-rays is recommended.

Application of CBCT in reconstructive dentistry (G. Benic and S. Hicklin)

Evaluation of existing prosthetic abutments

Currently there is no published evidence for direct benefits that would justify the use of CBCT in reconstructive dentistry (e.g. for the evaluation of the coronal tooth structure or to obtain a three-dimensional full-mouth overview). In overlapping dental specialties (e.g. periodontology and endodontology) there are, however, several potential indications for the use of CBCT supporting the correct diagnosis and the successful treatment of future prosthetic abutments. The importance of periodontal and endodontic diagnostics rises with the increasing complexity of the reconstructive treatment and strategic importance of the prosthetic abutment (Flack et al. 1996, Pihlstrom 2001, Kim & Mupparapu 2009, Cardoso et al. 2012).

Teeth in need of prosthetic treatment often contain restorative materials (e.g. root canal filling, endodontic post, filling or crown). It is well known that, in CBCT, artifacts appear in the proximity of radio-opaque restorative materials, which may hamper the correct visualization of the tooth under investigation (Schulze et al. 2011, Camilo et al. 2013).

When evaluating existing prosthetic abutments, the following recommendations for the use of CBCT should be considered:

- For prosthetic treatment planning, the use of CBCT to evaluate the remaining coronal tooth substance is not indicated.
- There is no need to use CBCT for the evaluation of a potential abutment tooth when clinical and two-dimensional radiographic examination show endodontically and periodontally healthy situations.
- When evaluating osseointegrated implants as potential abutments for the support of prosthetic reconstructions, the use of CBCT is not recommended.

- When evaluating periodontally or endodontically compromised teeth as potential abutments for the support of prosthetic reconstructions, the guidelines for the use of CBCT provided in the preceding sections on Endodontology and Periodontology should be followed.

Implant dentistry

Dental implants are used to replace missing teeth. Preoperative prosthetic diagnostics and the prosthetically driven implant placement are, therefore, prerequisites for the accomplishment of a biologically, functionally and esthetically ideal treatment result. The importance of prosthetic diagnostics increases with the extent of the proposed reconstruction and complexity of the treatment.

The standard preoperative diagnostic procedure in implant dentistry involves the clinical and the two-dimensional radiographic assessment (Harris et al. 2012). However, the two-dimensional radiographic assessment often leads to an underestimation of the amount of bone that can affect the correct treatment modality, e.g. bone augmentation procedure or type of reconstruction (Temmerman et al. 2011, Fortin et al. 2013). Compared to conventional two-dimensional radiography, CBCT provides higher sensitivity for the identification of sites that are suitable for implant placement (Fortin et al. 2013). One recent clinical study suggests that, in selected situations, CBCT in combination with software for implant planning has the potential to enhance the treatment predictability by identifying an ideal implant position with respect to the prosthetic reconstruction (Arisan et al. 2013).

Visualization of the planned implant-supported reconstruction in the CBCT image is essential for the definition of the treatment plan. This can be obtained either by means of a radiopaque template or by superimposing a three-dimensional digital image of the prosthetic set-up onto the CBCT image. Such comprehensive preoperative imaging may subsequently allow the identification of the best possible compromise with respect to the surgical and the prosthetic treatment options. Nevertheless, there is as yet no evidence to suggest that computer-assisted surgery is superior to conventional procedures in terms of safety, outcome, morbidity, or efficiency (Tahmaseb et al. 2014).

Before prescribing CBCT scans, preexisting CBCT data sets should be scrutinized and, whenever possible, used for implant planning. When selecting the CBCT scan setting, a low-resolution protocol is generally sufficient to identify the relevant anatomical structures and to obtain the diagnostic information needed for implant planning (Dawood et al. 2012).

Planning an implant involves decisions on the number of implants, implant position, type (e.g. two-piece, one-piece), design (e.g. tapered, cylindrical), diameter, length and prosthetic platform. The plan should take into consideration both the anatomy and the predetermined prosthetic reconstruction.

Recommendations for the use of CBCT:

- If the clinical and the two-dimensional radiographic evaluation of the implant site reveal the relevant anatomical structures and a sufficient amount of bone for implant placement in the ideal prosthetic position, the use of CBCT is not justified.
- In situations with limited vertical or horizontal dimension of the alveolar ridge in which on the basis of clinical examination, the two-dimensional X-ray images, and the prosthetic diagnosis, a lateral bone augmentation or sinus elevation with lateral antrostomy is anticipated, the use of DVT is justified. In cases with unfavorable bone morphology and where there is low tolerance regarding the correct implant position (e.g. fixed implant-supported reconstruction in the esthetic region), the use of CBCT in combination with guided surgery may be beneficial to optimize the implant position.
- If minimally invasive (flapless) surgery is intended, the use of CBCT in combination with guided surgery is often recommended.
- When immediate implant restoration is planned, the use of CBCT in combination with guided surgery may be beneficial to obtain sufficient primary implant stability.
- Surgical aspects of implant dentistry were covered in Part I of this consensus report (Dula et al. 2014).

Application of CBCT in pediatric dentistry (K. Dula and D. Dagassan-Berndt)

The use of X-rays for detection of caries in children is widely accepted (Neuhaus et al. 2009, Twetman et al. 2013). However, the latest studies suggest that they could be, at least partly, replaced by alternative methods that are currently under development (Huth et al. 2008, Novaes et al. 2009, Huth et al. 2010, Neuhaus et al. 2011, Sochtig et al. 2014). In populations with a low caries prevalence, it has even been suggested that meticulous visual inspection is sufficient for caries detection in both children and adolescents (Baelum et al. 2012, Mendes et al. 2012). The use of CBCT for caries detection has been the subject of several studies (Kamburoglu et al. 2010, Charuakkra et al. 2011, Kayipmaz et al. 2011, Wenzel et al. 2013). However, in light of the above-mentioned new opportunities and because other studies found no benefit in caries detection with CBCT (Zhang et al. 2011, Qu et al. 2011, Cheng et al. 2012, Rathore et al. 2012, Valizadeh et al. 2012), no justification can be found for the use of CBCT for caries detection. The usefulness of CBCT in pediatric dentistry is therefore limited to specific diseases of children. These are generally diseases with greater importance to the overall health of the child, such as specific or severe inflammations, bone diseases, benign and malignant tumors or other very special pathological conditions.

Discussion

The first and second consensus conference of the SADMFR led to the development of guidelines that cover in detail all aspects of dentistry. This is considered to be one of the invaluable outcomes of this work. At the time when the second consensus conference was being planned only a few real indications for the use of CBCT were apparent in the areas that were to be discussed. A thorough study of the topic, a more critical consideration of the various aspects and a detailed analysis of the existing literature allowed a clearer opinion to be expressed on the relevance of CBCT to the various disciplines. This and the critical discussion by all members of the conference led to new decisions, which are presented in this article as guidelines for the use of CBCT in dentistry.

Currently, for discussions on biological risks associated with low radiation doses, the linear no-threshold model (LNT model) proposed by the International Commission on Radiological Protection (ICRP) is generally accepted (ICRP 2007). This model states that the risk of additional fatal cancers and/or heritable disorders at radiation doses greater than zero increases in direct proportion to the dose. Therefore, the application of CBCT in the areas discussed in this paper must be subject to careful consideration, because the findings from the clinical examination and the two-dimensional imaging usually do ensure proper patient treatment. This is especially true in periodontology, where the periodontal probe and the periapical radiograph are the standard methods for metric diagnosis (Walter et al. 2011). However, difficult defect morphology in cases with strategically important teeth may require the use of CBCT.

In recent years, methods in endodontology have been developed that have opened up new possibilities for diagnosis and treatment and have proved partly able to replace X-ray images (Shabahang et al. 1996, Perrin et al. 2014). This applies particularly to the electronic measurement of root canal length by means of impedance devices and to microscope-assisted endodontics. A second root canal in the mesiobuccal root of upper first and second molars, for instance, can more reliably be found with a microscope than with CBCT, even if the CBCT machine provides high-resolution imaging. A microscope does not apply any radiation dose and its use leads seamlessly from diagnosis to therapy.

In reconstructive dentistry, the problem is that most of the potential indications relate to other specialties. Consequently, reasons that justify the use of CBCT in this area must be considered very carefully. However, new applications of CBCT are under development: the method of implant installation should be subordinate to the required shape of the superstructure, to ensure that in an individual patient an ideal occlusion at maximal intercuspidation can be achieved. This requires planning the treatment with three-dimensional visualization, from the fabrication of drilling templates for implant placement to the reconstruction of virtual master casts, and the modeling of prefabricated crowns or bridges for the individual concerned. New hard- and software has already been produced for this purpose and is under constant development. This allows a single workflow, in which, however, three-dimensional imaging is an absolute necessity. Future studies will be needed to determine in how many cases an implant placement driven by an ideal superstructure can really be performed and whether the benefits to the patient justify the use of this type of X-rays, costs of treatment planning and therapy.

In pediatric dentistry, the use of ionizing radiation must be justified with even greater caution because there is broad consensus that the tissues and organs of children and adolescents are more sensitive to radiation than those of adults (Pierce et al. 1996, Pearce et al. 2012, Mathews et al. 2013). The reasons for this include the rapid rate of cell division of the growing tissue; the smaller volume of the body, which allows more radiation-sensitive organs and tissues to be exposed when the aperture is not suitably adjusted; the still immature cell repair mechanisms; the higher radiation sensitivity of the red bone marrow; and the higher life expectancy of children which allows them to experience radiation damage after the long latent period (Brody et al. 2007).

However, the previously specified values of a 10 to 15-fold (Pierce et al. 1996) or 3 to 5-fold higher radiosensitivity (Marine et al. 2010) can most probably no longer be supported. Volume II of the UNSCEAR 2013 report, which deals with the effects of radiation exposure in childhood, concludes that the estimates of lifetime cancer risk for those exposed as children are uncertain and might be a factor of 2 to 3 times higher than estimates for a population exposed at all ages (UNSCEAR 2013). The report states that for some organs and tissues the radiation risk is considerably higher for children than for adults, other organs and tissues have about the same radiosensitivity as adults, and for some organs and tissues children appear less sensitive to radiation exposure than adults. The report recommends that generalizations about the risks of effects of radiation exposure during childhood should be avoided.

We know that, owing to their proximity to the center of the Japanese atomic bomb (A-bomb) explosion, 30,000 of the 86,572 people followed in the Life Span Study were exposed to a dose equivalent to the one often delivered during computed tomography (CT) in children (Preston et al. 2003, Preston et al. 2007). Information on the doses of CT scans in children has been published in recent years. The children and adolescents observed in these studies underwent investigations with CT at doses from 0.3 to 20 mSv, which were performed for medical reasons (Mettler et al. 2008). These studies all agree that after a number of years a significantly increased incidence of malignant tumors can be found in these children compared to non-exposed controls (Brenner et al. 2001, Chodick et al. 2007, Pearce et al. 2012, Mathews et al. 2013, Miglioretti et al. 2013). Other studies on the biological effects of CT scans consistently show that the probability of developing a malignant tumor is positively correlated with the number of CT scans and negatively correlated with age (Brenner & Hall 2012). In a large-scale study, Mathews et al. were able to document a dose-response relationship between the number of CT examinations performed and the occurrence of cancer in children aged from 1 to 19 years. With each CT scan the probability of developing a malignant tumor increased, depending on age, by a factor of 1:06 to 1:45 (Mathews et al. 2013). Cardis et al. found that the low-dose A-bomb cancer risk data are consistent with the results from large-scale epidemiological studies in workers in the nuclear industry (Cardis et al. 2007). Thus, we now have cancer risk estimates for the dose range that coincides with the measured organ doses from pediatric CT. This makes the assumptions or extrapolations for the biological risk from the difficult-to-compare irradiation by the A-bomb unnecessary – the risk can be calculated directly (Hall 2002).

Theodorakou et al. calculated the lifetime attributable risk of a dental CBCT in a 10-year-old and an adolescent patient, with an average effective dose of 0.116 mSv and 0.079 mSv, respectively, and estimated a corresponding lifetime attributable mortality risk of 0.00174% for 10-year-old childen and 0.00089% for 15-year-old adolescents (Theodorakou et al. 2012). These values can be considerably higher in other CBCT machines (Ludlow & Ivanovic 2008, Pauwels et al. 2012) and they are always much higher than the effective dose of 0.001–0.0083 mSv that was indicated for two bitewing radiographs (Aps 2013, Aps & Scott 2014). The greatest concern would arise where CBCT might be involved in the recall system to be used in place of bitewing radiographs for repeated caries detection.

Bitewing radiographs have been broadly accepted in children because of their considerable advantages for early detection, high specificity and high sensitivity (Neuhaus et al. 2009, Twetman et al. 2013). The latest studies suggest that bitewing radiographs could be, at least partly, replaced by alternative methods that are currently under development (Huth et al. 2008, Novaes et al. 2009, Huth et al. 2010, Neuhaus et al. 2011, Sochtig et al. 2014). In populations with a low caries prevalence, meticulous visual inspection for caries, both in children and adolescents, has lately even been described as sufficient (Baelum et al. 2012, Mendes et al. 2012).

CBCT machines have a wide range of doses (Pauwels et al. 2012), and also vary considerably in image quality (Liang et al. 2010) in terms of resolution, noise and sharpness. The effects of the proprietary software and image destruction by artifacts at interfaces with high contrast make it impossible to use CBCT for reliable caries diagnosis in daily practice (Haiter-Neto et al. 2008, Young et al. 2009).

Taking into account all of the above-mentioned points (CBCT applies the highest dose in dental radiology, the large differences between the different CBCT devices with regard to the delivered dose, the considerable uncertainty in tomographic images regarding image quality and artifacts in the crown area, the high diagnostic accuracy offered by "low dose bitewings", and the promising developments in the use of alternative diagnostic methods for caries), the SADMFR concludes that the use of CBCT is unacceptable for caries detection.

Résumé

En 2011, la première conférence de consensus de la Société suisse de radiologie dentaire et maxillo-faciale (SSRDMF) a eu lieu pour élaborer des lignes directrices concernant l'utilisation de la tomographie volumétrique numérisée (TVN) en radiologie dento-maxillo-faciale. Les thèmes traités concernaient la chirurgie orale et maxillo-faciale, le dysfonctionnement et les maladies de l'articulation temporo-mandibulaire et l'orthodontie.

En 2014, une deuxième conférence de consensus de la SSRDMF a été convoquée avec comme but d'élaborer des lignes directrices concernant l'utilisation de la TVN en parodontologie, endodontologie, en médecine dentaire reconstructive et en médecine dentaire pédiatrique. Les lignes directrices s'adressent à tous les dentistes pour les aider à prendre une décision lors de l'utilisation de la TVN.

De manière générale, les indications pour l'utilisation de la TVN sont restrictives, car les risques de radiations rendent une utilisation en routine impossible. La TVN doit être réservée à des cas complexes de difficultés supérieures et pour lesquels, grâce à l'utilisation de la TVN, on peut s'attendre à des informations supplémentaires qui sont importantes pour la thérapie. En parodontologie, l'information générée avec l'examen clinique et les radiographies de dents isolées est souvent suffisante. En endodontologie, on peut souvent travailler avec des méthodes alternatives et en médecine dentaire reconstructive, la TVN est principalement utilisée pour le workflow de la planification jusqu'à la réalisation de la suprastructure des patients avec implants. En médicine dentaire pédiatrique, il n'y a aucune indication d'utiliser la TVN pour le diagnostic de caries.

Zusammenfassung

Im Jahr 2011 wurde von der Schweizerischen Gesellschaft für Dentomaxillofaziale Radiologie (SGDMFR) eine erste Konsensuskonferenz zu Leitlinien für den Einsatz der digitalen Volumentomografie (DVT) in der dentomaxillofazialen Radiologie einberufen. Diese behandelte Themen der Oral- und Kieferchirurgie, der Dysfunktionen und Erkrankungen der Kiefergelenke und der Kieferorthopädie.

Im Jahr 2014 tagte die zweite von der SGDMFR einberufene Konsensuskonferenz zu Leitlinien für den Einsatz der DVT in der Parodontologie, der Endodontologie, der rekonstruktiven Zahnmedizin und der Kinderzahnmedizin. Die Leitlinien sind für alle Zahnärzte gedacht, sie sollen ihnen zur Entscheidungsfindung beim Einsatz der DVT dienen.

Generell werden die Indikationen zur DVT restriktiv gesehen, denn Strahlenrisiken verunmöglichen den routinemässigen Einsatz. Die DVT sollte komplexen Fällen mit höherem Schwierigkeitsgrad vorbehalten sein, bei denen durch den Einsatz der DVT eine eindeutige, therapierelevante Mehrinformation erwartet werden kann. In der Parodontologie sind mit der klinischen Untersuchung und mit periapikalen Röntgenbildern meistens ausreichende Informationen vorhanden, in der Endodontologie kann oftmals mit alternativen Methoden gearbeitet werden, und in der rekonstruktiven Zahnmedizin steht die DVT bei Implantatpatienten im Workflow von der Planung bis zur Suprakonstruktion im Vordergrund. Für die Kinderzahnmedizin werden keine Anwendungen der DVT zur Kariesdiagnostik gesehen.

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