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Scientific article

Revised consensus guidelines for the use of cone-beam computed tomography/ digital volume tomography

Results from a consensus process organized by the Swiss association of dentomaxillofacial radiology

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Swiss guidelines, guidelines, CBCT, cone-beam computed tomography, three-dimensional imaging

Abstract

Cone beam computed tomography (CBCT) is established in dentistry for about 20 years. Technique evolved and indications clarified since then and since the Swiss consensus guidelines regarding CBCT were published in 2014 and 2015. Therefore, the Swiss association of dentomaxillofacial radiology decided to initiate the process of updating these guidelines by forming a consensus group divided into a core group responsible for the whole process and an approval group responsible for specific clinical matters. The manuscript outlines the revised guidelines in a practical way and is divided along the different specialties and clinical fields of dentistry. In result the guidelines are updated regarding reconstructive dentistry, orthodontics, geriatric dentistry, temporomandibular joint disorders, maxillofacial traumatology, benign and malignant tumors, assessment and detection of dental foci and endodontic infections and apical surgery. Overall, it can be stated that CBCT is utilized more consistently and somewhat broader than ten years ago. Today CBCT is well established and has proven benefits if indicated and analyzed precisely. Therefore, it might very well become more and more standard in dental radiology.

Introduction

About 20 years ago the first cone-beam computed tomography (CBCT) devices for radiological 3D diagnosis in dentistry were installed in Switzerland. These CBCT devices had been developed for use in private dental practices (1). Until then, three-dimensional (3D) imaging diagnostics in dentistry had mostly been used for tumor or fracture diagnosis by means of computed tomography (CT), which had to be done in dedicated radiological units in hospitals, medical practices, or some dental universities. With the advent of CBCT technology, indications for 3D-imaging which earlier were strictly limited (wisdom teeth or implant dentistry) became more and more established in dental medicine (2-9).

For guidance on correct indication and radiation protection, the SADMFR decided to establish guidelines for the use of CBCT in dentistry in two articles about a decade ago (10, 11). Ten years have passed since the publication of the Swiss guidelines on the use of CBCT. The SADMFR believes that these recommendations need to be revised and updated as the use of CBCT in dentistry has expanded drastically, which is also reflected by the increasing number of publications on this topic (Fig. 1).

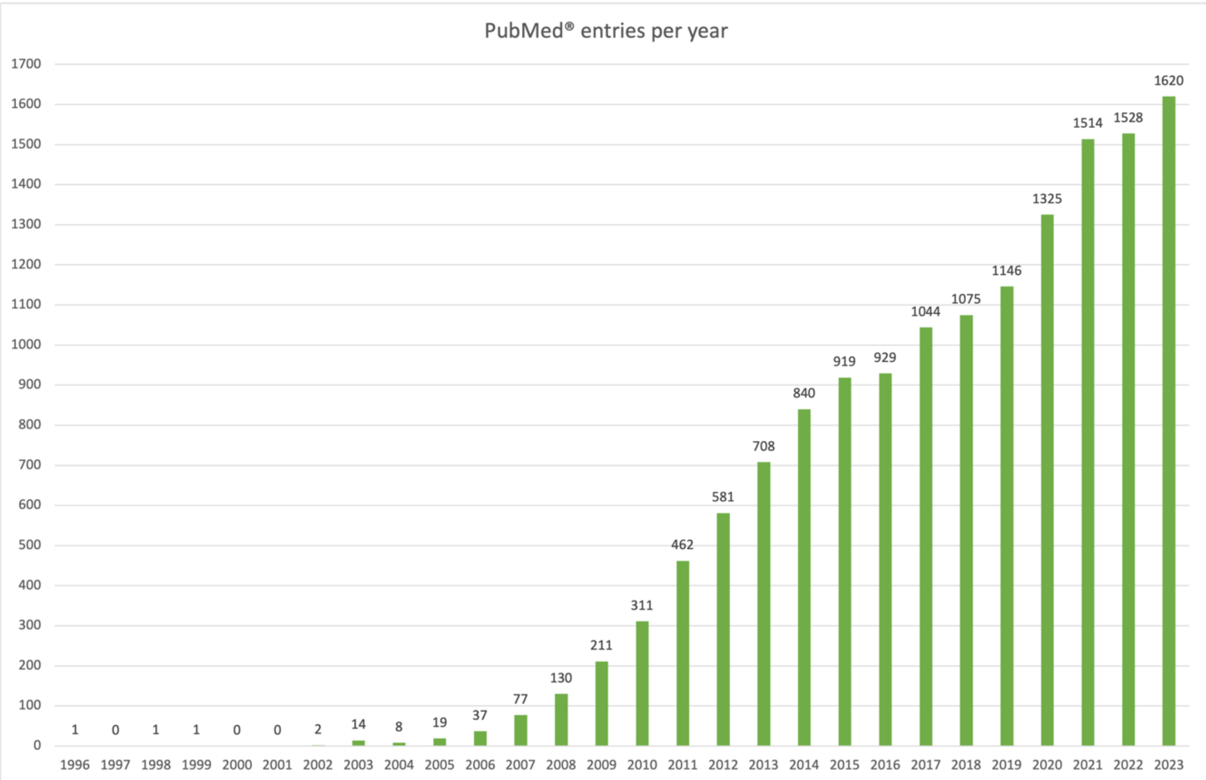

Figure 1. Number of PubMed entries per year with the following search query: (cbct) OR ("cone beam CT") AND (dentistry). Data retrieved from https://pubmed.ncbi.nlm.nih.gov/ on Nov 24th, 2024.

Materials and methods

The SADMFR decided to organize this third consensus conference online. The process was initiated on February 18, 2021. To keep the effort for preparation and implementation of the revision of these guidelines within reasonable time and resource limits, a core group of six members was appointed by the board of the SADMFR to prepare the revised guidelines comprising of recognized colleagues in Switzerland in the field of dentomaxillofacial radiology. This core group covered the areas of oral surgery, dentomaxillofacial radiology and stomatology / oral medicine with expert level knowledge. Thus, other experts were consulted on areas that did not fall within the expertise of the core group. These additional experts became part of an "approval group" to whom the revised publications were sent as a proposal with the request to check and add comments or improvements for their specific topic. The "approval group" included experts from the following specialties: TMJ dysfunction and disease, periodontology, implantology, reconstructive dentistry, orthodontics, geriatric, and pediatric dentistry. All members of the "approval group" had the opportunity to include other experts from the relevant areas in the discussion, which gave the guidelines even broader support. All members of the "approval group" thus became “group leaders” and thus the contact person for the SADMFR in the respective specialist’s area.

All proposals and corrections made by the approval group were incorporated into the text prepared by the core group. This revised text was then sent back to all members of the core group for comments and additional corrections. As a last step, a final meeting of the members of the core group took place to come to a consensus including discussions of all chapters focusing on specialties as mentioned above.

Results and Discussion

Imaging settings and general recommendations (approved by all authors)

Creating CBCT images comprises four components: acquisition configuration, image detection, image reconstruction and image display (12).

The acquisition configuration determines the image quality of CBCT scans (irrespective of moving artefacts), and therefore the application of dose. Prior to every CBCT scan, CBCT scanning protocols must be defined. Therefore, all clinical questions must be merged with an individual indication and justification.

First, the region of interest (ROI) must be defined and translated to the scanned field of view (FOV), which can contain a few teeth (= small FOV), a whole jaw (= medium FOV) or both jaws as well as neighboring anatomic structures for example the temporomandibular joints, maxillary sinuses or the orbit (= large FOV) (13). Second, the resolution of anatomical structures needed for visualization must be chosen according to the clinical questions. Most manufacturers provide a selection of different voxel sizes. The lower the voxel size, the higher the energy needed to generate good image quality and the higher the effective dose resulting for the patient (13, 14). Third, the number of raw images taken, range of rotation, scanning time and modulation of beam are other possibilities to influence image quality as well as effective dose. Multiple manufacturers provide special features with varying names, and operators are not able to directly compare these features (15-17).

General principles on the use of dental CBCT are stated as follows (14, 18):

- CBCT should only be carried out after acquiring a patient’s history and thorough clinical examination.

- CBCT imaging needs justification for image taking and already available radiographs should be considered.
- CBCTs should be taken only by dentists who underwent special training and qualification.
- Continuing education and training in CBCT including radiation dose protection issues even after basic training is mandatory.

Adapting CBCT scanning protocols to individual indications seems to be the most effective way to limit effective dose and provide sufficient data/image quality for diagnostic and treatment purposes in dentistry.

Localization/orientation of anatomical structures (low resolution)

For general visualization of teeth or the measurement of bone volume, the image resolution can be limited to lower the effective dose for the patient.

Whenever localization and the relation of entire teeth to neighboring structures or bone margins/ surroundings must be visualized (for example wisdom teeth and their relationship to the mandibular canal, or bone visualization for implant planning), a reduction of exposure parameters is possible (16, 19):

a. Reduction of FOV to smallest possible volume
b. Reduction of the electric current to 4-6 mA
c. Reduction of scan-time to standard mode instead of high-resolution mode or use of half rotation (180 degrees), keeping voxel-size up to 0.2/0.3 mm
d. Application of low-dose protocols, if available and if they enable an adequate resolution.
e. Choice of optimal voltage (e.g., 80-100kV), if possible.

Need for high resolution imaging

As soon as more refined details like the root canal system, root resorption, ankylosis or similar pathologies are needed for visualization, parameters should be adapted to:
a. reduce to the smallest FoV

b. choose the smallest possible voxel size available and

c. select the high(est) amount of image numbers within the scan (full rotation)

High resolution is needed to visualize rather small anatomical and/or pathological structures. Thus, the highest resolution and the smallest FoV are often needed. Some manufacturers provide the highest resolution with a small voxel size only in the smallest FoV.

To limit the effective dose to the maximum, the FoV always should be adapted to the smallest possible FoV.

As high-resolution imaging generally results in longer scan times than for standard protocols, children may not always be compliant when exposed to long scan times. Thus, settings with shorter scan times must be chosen in these cases. On an individual basis, decisions must be balanced between blurry-free images with lower resolution due to reduced scan times versus high-resolution images with the risk of motion artifacts (20, 21).

Conclusion: The correct CBCT settings regarding FoV, resolution, current and voltage must be chosen individually depending on patient and indication. Therefore, and due to its often sophisticated diagnostic evaluation, CBCTs should be taken only by dentists who underwent a special training and qualification.

Reconstructive dentistry (approved by Nicola U. Zitzmann and Tim Joda)

Restoration and replacement of missing teeth is the classic task of reconstructive dentistry (prosthodontics). Treatment planning of fixed and removable dental protheses needs visualization of both jaws in a radiographic overview to evaluate the individual situation of teeth and bone. Some detailed two-dimensional radiographs may be indicated to check caries lesions, restoration margins, and bone loss. Only rare cases of teeth requiring advanced periodontal, endodontic treatment or further assessment of pathologic bone conditions, need to have a CBCT scan conducted (see section Endo/Paro/Surgery). Digitalization, with methods like computer-aided design and computer-aided manufacturing (CAD/CAM) changed traditional workflows for the provision of implant-supported protheses. In some cases, where restoring missing teeth lead to involvement of dental implants, CBCT scans are needed in the setting of guided implantology or fully digital treatment (9). Patients in need of reconstructive dentistry are usually elderly adults. Due to the life span of these patients, radiation risk is reduced by the factor of 0.5 (30 to 50 year old patients) or even 0.3 (50 to 80 year old patients) of effective dose (18, 22). The caveat in these age groups is a high probability of restorations present in the oral cavity with high-absorbing (metal) material. Resulting artefacts may interfere with the diagnostic process and reduce image quality (23, 24). New algorithms reducing metal induced artefacts (MAS) are implemented in some CBCT scanners and shall help improve image quality (25, 26). Nevertheless, these artefacts make full-digital workflows difficult, especially matching intraoral scans with CBCT scans (27, 28). From this point of view, indications for adjunctive CBCT imaging must be considered carefully. Follow-up care in reconstructive dentistry follows ALARA principles and usually there is no indication for CBCT evaluation (10).

In conclusion the utilization of CBCT in reconstructive dentistry is rather rare and focusses on specific topics as e.g. implant planning, advanced periodontal or endodontic treatment, or visualization of complex trauma cases, in which the potential abutment teeth show e.g. clinical signs of invasive cervical resorption.

Orthodontics (approved by Raphael Patcas)

In orthodontics, two-dimensional radiographs such as panoramic views and lateral cephalograms are routinely and successfully used for diagnostics and treatment planning (29, 30). Magnification, distortions, superimpositions of unrelated anatomical structures, double-contours, landmark identification and head positioning errors are well known limiting factors in interpreting these radiographic images (30-34).

CBCT may prove advantageous in daily orthodontic practice to overcome these limitations to reach diagnostic certainty. In comparison to conventional radiographs, CBCT scans offer the benefit of a 3D representation of the volume in different visualization methods, such as multi-planar reformatted slices, intensity projections or as rendered surface models, and can thus be beneficial for the diagnosis of more generalized cranio-maxillofacial and localized dentoalveolar anomalies.

CBCT scans, which cover the same field of view of standard 2D orthodontic radiographs, cause, however a higher effective dose (35).

Sensitivity to radiation varies considerably with age. In general, radiosensitivity, i.e. the susceptibility of cells, tissues, organs or organisms to the harmful effects of radiation, decreases with age. This means that growing organisms are more susceptible to the effects of radiation. Accordingly, most orthodontic patients, are more vulnerable to radiation (36-38), and concerns relating to a potential carcinogen risk of higher radiation doses are especially relevant.

CBCT imaging is only justified if additional information needed for diagnosis or therapy planning can reasonably be expected (11), and should therefore be reserved for *subsequent* in-depth analysis of findings for which conventional 2D imaging diagnostics do not provide conclusive information (30). Therefore, a small field of view with high resolution will usually be the setting of choice in orthodontics.

Indications and benefits of CBCT scans in orthodontic patients were recently systematically reviewed (39) and broadly discussed (34, 40). The available literature analyzes the evidence-based benefits of CBCT for a plethora of orthodontic problems, which are predominantly dentoalveolar or more localized. These indications can be grouped into:

A. *Calcifications or anomalies* of dental structures: dysplastic teeth, root resorptions, ankylosis, supernumerary teeth and odontomas, teeth with dilacerations, gemination or invaginations (41);
B. *Topographical evaluation* of unerupted (retained, impacted, aberrated) teeth (39, 42);
C. *Assessment of bone*: alveolar bone covering of teeth (before or after treatment) and bone volume for insertion of temporary anchorage devices (43-45).

In practice, a case may evidently present multiple problems of different origins at the same time (e.g., root resorption of tooth adjacent to an impacted tooth).

Beyond these localized dentoalveolar abnormalities, studies also discuss the potential benefits of CBCT for various more generalized craniofacial deformities (34, 39, 40), with special emphasis on facial asymmetry (46, 47), cleft palate (48), temporomandibular joint disorders, oro-pharyngeal airway assessment (49-51) and planning for orthognathic surgery. As these cases usually require an interdisciplinary approach, requirements and settings needed should ideally be discussed and defined *prior* to the scan, as different specialists may have diverging expectations in the scanned volume (52).

Several alternatives have been suggested to avoid ionizing radiation in craniofacial imaging, such as magnetic resonance tomography (MRI) for the assessment of osseous pathologies in the TMJ (53) and mandibular growth (54), or 3D photography for facial asymmetry quantification (55). These non-ionizing options should be further evaluated as alternatives to CBCT, especially for children and adolescents.

In contrast to our first published guidelines (10), most CBCT devices now offer considerably more options for dose reduction, which should be implemented in each individual case (e.g., use of collimation settings by choosing the smallest FOV; or adjusting patient-related settings such as reducing exposure parameters and increasing voxel size according to the specific indication (56).

In conclusion, the lack of sufficient evidence cautions against the undifferentiated use of CBCT for all orthodontic patients, which are predominantly comprised of children or adolescents. There is no clear and established therapeutical benefit for the **routine use** of CBCT imaging over the established 2D radiographs for orthodontic treatment planning. Thus, CBCT should be reserved for cases in which 2D radiographs fail to provide sufficient diagnostic clarity or seem not sufficient for treatment planning purposes.

Gerodontology / geriatric dentistry

Geriatric dentistry focuses on dental care for elderly people, but there exists no clear age threshold to be termed a geriatric (dental) patient (57). Since some older people are generally healthy, they can be treated as any other patient (58). In addition to their age geriatric patients either suffer from typical age-related impairments, or simply overstrain a general or specialized dentist due to their multimorbidity and/or polypharmacy.

The basic rules for indication and utilization of CBCT as outlined in other chapters also apply for geriatric patients (17). The literature to date lacks data or recommendations regarding the use of CBCT imaging in gerodontology.

However, general considerations can be made for geriatric patients:

1) In elderly geriatric patients, the risk for the later development of malignant tumors due to exposition to radiation is significantly lower than in younger patients (10, 59-66).
2) Elderly and especially geriatric patients tend to have a lower capability for healing, due to a weaker general condition and medications taken. Furthermore, there is generally a higher risk for complications resulting from missed pathologies or dental, especially surgical, procedures.
   These patients may, for example, also suffer from inadequate nutrition, oral hygiene, and salivary quality, which especially influence individual caries risk, periodontal lesions, and functional abilities. Caries management by risk assessment (CAMBRA) as well as other systematic check-ups are needed to avoid caries, periodontal and other diseases to prevent invasive interventions.

Derived from these considerations, the indication for CBCT imaging in elderly and especially geriatric patients is more likely justified for the following indications:

- Detection of periapical lesions, as well as peri-implantitis may be crucial to general health for an older multi-morbid patient. If not treated, they can result in complications such as osteomyelitis in a patient with a weaker immune system or osteonecrosis related to antiresorptive therapy (bisphosphonates, denosumab), which is quite common in an elder patient population (67, 68).

- Implant related bone augmentation might be less preferable in geriatric patients while at the same time bone volume is often unfavorable. Therefore, three-dimensional diagnostics and guided surgery might be utilized to avoid bone augmentation and CBCT imaging is often necessary to achieve this goal (69-71).

- TMJ cases with suspected arthrotic changes might require CBCT as the modality of choice, since older patients present with a higher rate of bony alterations (72). It is also important to note that persisting TMJ symptoms can be sign of a malignant tumor, which is generally more likely in older patients (73-75).
- Special situations like infection from impacted teeth require CBCT to provide precise information on the patient's anatomy and its relation to the pathologic conditions (4, 5, 76, 77). This helps the clinician to better evaluate the need and type of intervention and, in case of surgical intervention, to minimize morbidity and potential complications, which is more crucial in geriatric patients (2, 3, 77).

In the future, for example, methods of artificial intelligence could be able to deeply analyze radiological image data and create preventive approaches in health care. For example, measurements of bone mineral density (BMD) in CBCT taken for dental purposes might identify patients at risk of osteoporotic fractures. It has been shown that CBCT (as well as and maybe better than panoramic imaging) can distinguish between women with osteoporosis and those with normal BMD (78-80).

As a practical recommendation, we suggest scanning in a sitting position, employment of restraining measures (such as the chin rest, arm support, head restraint, and bite-blocks) and rehearsal of the scanning procedure prior to the actual scanning. This should be done to avoid motion artifacts as much as possible, which are more pronounced in elderly patients (20).

In conclusion, the indication for CBCT imaging can be justified in older patients. Of course, sometimes CBCT may not be indicated because treatment is minimized due to various considerations in severely multimorbid patients and a pathological condition that does not impair quality of life. On the other hand, in today's daily clinical routine it's more a lack of access to treatment and recognition of geriatric patients' needs than a balanced decision that leads to diagnostics and minimized treatment.

Temporomandibular joint disorders (approved by Jens C. Türp)

The basic recommendations for the use of CBCT in the radiological assessment of the temporomandibular joints (TMJs) have not changed since the first publication of these guidelines (11). In the meantime, however, CBCT has become even more widely available, and it is reasonable to assume that it is being used more frequently in clinical practice for TMJ imaging than it was a decade ago.

Although panoramic radiography can provide basic information about the TMJs, its visualization is compromised by severe shape distortion of the condyle due to the nonorthogonal orientation of the x-ray beam (81). Therefore, even before CBCT became available and popular, further imaging was recommended when degenerative changes in the TMJ were suspected (81). CBCT allows for the imaging of the bony components of the TMJs without any superimposition or distortion (82). Compared to panoramic radiography and (linear/spiral) tomography of the TMJs, CBCT offers a higher diagnostic accuracy, e.g. for cortical erosion (83). Therefore, its strength lies in the detection of any bony changes of the articular condyle, the temporal fossa, and the articular eminence, such as destructive-erosive remodeling, deformations, flattening of the articular surfaces, osteophyte formation, subchondral sclerosis and ankylosis (84-87). In order to fully extract all this information, it is crucial to access the original 3D-dataset of the CBCT and not only refer to single plane views (5, 13). The fact that the TMJ is not oriented in the main orthogonal planes emphasizes this requirement.

In order to obtain optimal information, it is recommended that the preferred occlusal position (e.g., closed jaw, open jaw, prosthesis-related) be accurately selected during the CBCT scan and noted in the radiologic report. Of course, this recommendation also applies to all other TMJ imaging modalities.

Compared to conventional computed tomography, CBCT is widely available, cost-efficient, and generally results in lower dose exposure to the patient. CBCT was developed for specific diagnostic needs of dentistry. However, while hard tissues are very well depicted, soft tissue have very uniform gray values. Therefore, CBCT images do not provide sufficient information about the intra- and periarticular soft tissues, such as the articular disc, the TMJ capsule, synovial fluid or ligaments. For visualization of these tissues, MRI is the imaging modality of choice, usually also showing calcified tissues with sufficient diagnostic detail (88).

In addition, there is evidence that ultrasound (US) imaging has the potential to evaluate acute and chronic TMJ changes, although with slightly less accuracy than MRI. However, following a baseline MRI, US may further increase diagnostic sensitivity and specificity(89).

Despite advances in orofacial imaging, the mainstays of TMJ diagnosis are a thorough patient history that includes somatic (Axis I) and, especially in the case of persistent/chronic pain, psychosocial (Axis II) aspects, and clinical examination. Additional information obtained from CBCT images often does not lead to a change in therapeutic decisions in patients with TMJ problems (90). Therefore, CBCT is *not* indicated for routine diagnosis in daily dental practice. Other radiologic modalities, such as panoramic radiography, are also inappropriate for a meaningful therapy-oriented assessment (91, 92), but may be used for differential diagnosis.

However, CBCT (as well as MRI (93)) provides objective information about tissue changes, the progression of pre-existing pathology and, in special cases, whether surgery should be considered. Therefore, CBCT may be indicated in patients with failure of conventional therapy, trauma, severely decreased jaw opening, systemic joint disease, and suspicion of tumor (Petersson 2010).

It is also important to remember that persistent TMJ symptoms of almost any type may be a sign of a serious underlying pathology, such as neoplasia, although this is very rare (73-75).

In conclusion, CBCT has emerged as a relatively cost-effective and dose-effective imaging modality for the diagnostic evaluation of a variety of TMJ pathologies. However, the diagnostic information obtained is limited to the morphology of the osseous joint components, cortical bone integrity and subcortical bone destruction (94). In general, and as in other fields of medicine and dentistry, the decision to obtain a CBCT or MRI (or any other non-basic diagnostic matter) should be made in a setting that is likely to provide adequate therapy (88). Thus, in many cases where these imaging modalities are considered, a referral to a TMJ/TMD specialist may be the more prudent decision, consistent with dose protection considerations.

Thus, the final decision regarding the appropriate imaging required rests with the clinician managing the patient. The clinician will generally choose CBCT imaging if there is any suspicion of bony changes that are relevant to clinical diagnosis and therapy.

Maxillofacial traumatology (approved by all authors)

The list of 3D imaging indications for cranio-maxillofacial traumatology is broad and is also considered as the imaging technique of choice in situations as listed in Table 1. In the case of trauma in the dentomaxillofacial region, which mainly involves hard tissue, CBCT is preferable. It has become a widely used technique and should be considered often instead of conventional multi-detector computed tomography (MDCT) due to its easy accessibility, ease of use, and good bone visualization (88, 95-97). The option of CBCT regularly applies to midfacial and mandibular trauma with no suspicion of intra-cerebral hemorrhage. While 2D-imaging – mainly due to massive superimposition of complex local anatomy - provides only limited insight in existence, course and dislocation of fractures, 3D-imaging – especially through free choice of section plane (5) – allows thorough evaluation and treatment planning. As a primary diagnostic alternative, MDCT low dose protocols for sole bone visualization have emerged over the last decade and are recommended more commonly today. They potentially solve the quite common "emergency room dilemma" of having a MDCT - but not a CBCT scanner available in most hospitals' primary trauma units. However, they are - aside from childhood trauma - not stringently practiced yet. One must remember: dose considerations in emergency patients (even if discussed repeatedly in studies) play a subordinate role. What matters most in this context is to gain a comprehensive picture as quickly as possible.

Table 1. Indications for 3D imaging in cranio-maxillofacial trauma.

General situation	3D imaging / CBCT indicated	3D imaging / CBCT not indicated
Cranio-maxillofacial Trauma with need for 3D-imaging	No suspicion of intra-cerebral lesion or other relevant injury of soft tissues	Suspicion of intra-cerebral lesion or other relevant injury of soft tissues (CBCT might be combined with MRI)
Prior to open reduction internal fixation	- Complex fractures of all kinds (98) Schoen et al., (99) Pohlenz et al., (100) Pohlenz et al. - Collum fractures (98) Schoen et al.	If conventional x-ray provides clear information (98) Schoen et al., (101) Zizelmann et al., (102) Drage et al.
Orbital wall fractures	No suspicion of relevant soft tissue injury, e.g., muscle incarceration, ophthalmic nerve trauma or retrobulbar hemorrhage (101) Zizelmann et al., (102) Drage et al.,	Suspicion of relevant soft tissue trauma, e.g., muscle incarceration (102) Drage et al. ophthalmic nerve trauma or retrobulbar hemorrhage (CBCT might be combined with MRI)

	(103) Blumer et al., (104) Blumer et al., (96) Brisco et al.	
Clinical situation with inconclusive conventional x-rays	Influence on treatment expected	No influence on treatment expected
Foreign body	Foreign body is radiopaque → CBCT is suggested for localization (105) Stuehmer et al., (106) Eggers et al., (107) Grobe et al., (108) Sadiq et al., (99) Pohlenz et al., (100) Pohlenz et al.	Foreign body is not radiopaque → MRI is suggested for localization (106) Eggers et al.
Intraoperative imaging (3D c-arm, CBCT) (109) Luebbers et al.	- Immediate control and revision in reposition and retention of complex fractures (107) Grobe et al., (99) Pohlenz et al. (instead of postoperative 3D imaging) - To spare a prior anesthesia for 3D imaging, e.g., in young children with clear indication for surgery based on 2D-imaging but necessary 3D imaging for the procedure (99) Pohlenz et al.	If intraoperative real time navigation is available, the need for intraoperative 3D imaging might be reduced (110) Lubbers et al.
Intraoperative computer navigation (111) Lubbers et al., (112) Lubbers et al., (113) Lubbers et al., (114) Luebbers et al.	To obtain a dataset needed for referencing / registration (115) Bettschart et al., (116) Venosta et al.	If an existing dataset of a different modality can be utilized (117) Sun et al., (118) Sun et al.
Patient specific models or implants (119) Quereshy et al., (120) Fernandes et al.	If an extra dataset is needed	If an existing dataset of different modality can be utilized

For specific cases involving neural structures including the facial or inferior alveolar nerve, high resolution MRI imaging is discussed and has, of course, the advantage of being a non-ionizing technique (121-125).

Three-dimensional data sets required for intraoperative surgery (treatment planning) or postoperative control (follow-up) are considered a routine application for CBCT (97). When radiopaque foreign bodies need to be diagnosed, such as in shotgun injuries, CBCT might be superior to MDCT due to reduced artifacts (105). However, in acute gunshot injuries, soft tissue images with detailed information on the large vessels are regularly required. In such extended trauma, CT angiography or MRI are often indicated as CBCT cannot visualize these tissues. Lastly, ultrasound can be utilized for soft tissue evaluation in the neck area but is limited, for example, in the midface region, due to the interference of bony structures.

In conclusion it must be stated that due to the complex anatomy in question and availability, radiation dose and costs of the technique CBCT is widely utilized in maxillofacial traumatology. It is today's technique of choice when trauma has to be evaluated and / or treated.

Benign and malignant tumors (approved by all authors)

CBCT is often the three-dimensional imaging technique of choice when examining benign bone tumors of the jaw. This due to its - compared to MDCT – high availability and generally low radiation dose, which can be further reduced by FOV-containment, while providing a similar excellent representation of the hard tissues (66, 126-130). For follow-up assessments or when choosing a wait-and-see-strategy of benign bone tumors of the jaw to visualize changes, the use of CBCT has the same advantages as mentioned for the initial assessment of these tumors (130, 131).

Regarding malignant bone tumors of the jaw, MDCT or MRI with a contrast medium is often imperative and provides the necessary information about soft tissue infiltration and lymph node involvement for radiological staging (132). In addition, MRI is classically known for its capability of detailed visualization of the soft tissue to facilitate in the diagnostic workflow. It was suggested that CBCT can be helpful in specific cases in assessing localized bony infiltration of squamous cell carcinomas (133-138). Psychologically valuable is CBCTs high availability "on site", which allows immediate feedback about the important question of bony infiltration (130).

In conclusion, for the re-evaluation or follow up assessments of malignant bone tumors, MDCT and not CBCT imaging is considered as the gold standard and should be applied. However, after therapy of malignant tumors, CBCT is often indicated when the indication for imaging is of a reconstructive nature but not to evaluate the disease or a possible relapse. Table 2 summarizes indications and contraindications for CBCT for assessing benign and malignant maxillofacial tumors.

Table 2. Typical indications for CBCT in head and neck oncology.

General situation	CBCT indicated	CBCT not indicated
Bone invasion of soft tissue malignoma in dispute (136) Momin et al., (135) Closmann et al., (139) Ziegler et al.	- Invasion through inner cortical layer in question? - Invasion of mandibular canal in question? - Immediate information desirable.	Amount of bone invasion is cleared by other (necessary) imaging techniques as, e.g., MRI or MDCT

Intraosseous tumors (131) Nakagawa et al.	- Structure and localization of lesion - Prior to biopsy (surgical access planning) - Follow up controls of lesion size (e.g., central giant cell granuloma under systemic therapy)	Need for soft tissue evaluation (could however be used in combination with MRI)
Angio CBCT	Only in clinical studies	Clinical routine
Positioning CBCT prior to radiotherapy session (140) Osman et al., (141) Xu et al.	Only in clinical studies	Clinical routine
Intraoperative computer navigation (111) Lubbers et al., (112) Lubbers et al., (113) Lubbers et al., (114) Luebbers et al.	Additional dataset is needed, e.g., with fiducials	Existing dataset of different modality can be utilized, e.g., by surface laser registration
Patient specific models or implants (119) Quereshy et al., (120) Fernandes et al.	Extra dataset needed	Existing dataset of different modality can be utilized

Assessment and detection of dental foci (approved by all authors)

There are many aspects about so-called dental foci, their diagnosis, and treatment in alternative or non-conventional medicine. All of those are not covered by this chapter, which is limited to evidence-based concepts and recommendations in (dental) medicine.

A dental focus has rarely been proven to be responsible for a single event / medical condition and studies even question the benefit of dental treatment, for example, prior to heart valve surgery (142). However, the fact that “medicine forgets dentistry” is an existing problem (143, 144). There is a risk of a dental focus to evolve into a medical problem in medically compromised patients, and sometimes this dental cause is missed.

The necessity to identify dental foci can basically be addressed from two sides. On the one hand, there are young and healthy patients, in whom a dental focus should be ruled out for general reasons in a first appointment or during routine recall visits. Missing a focus in these patients would very likely only lead to minor problems such as pain or a localized dental abscess. On the other side, missing a focus in a severely ill patient scheduled, for example, to undergo radiotherapy in the head and neck region or prior to an organ transplantation or to a heart valve replacement might result in severe consequences as e.g. osteoradio- or -chemonecrosis.

In consequence, the meticulousness and rigor of a dental focus assessment differs is influenced mostly by the potential risk posed to the individual patient due to a missed pathology. So even if screening for the same pathology, the means to do this differ significantly. Dental foci occur in many forms. Many of them are visible by a careful clinical examination. However, radiological techniques are an additional and mandatory aspect to provide information about incidental findings. While some of these have no clinical relevance (e.g., Stafne bone cavities) others (retained teeth, cysts, etc.) obviously do (145-147). Whenever it comes to the evaluation of root canal filled teeth or other nonvital teeth to detect periapical lesions, panoramic views and apical films are the standard screening techniques (148, 149). However, as well proven in comparison to CBCT, they lack sensitivity (Table 3) (150-158). CBCT is also superior in the diagnosis of vertical root fractures, a pathological condition which also represents a dental focus (159-162).

Since CBCT is widely available nowadays, it is reasonable to utilize it for the identification of chronic periapical periodontitis in selected cases, to assess and detect dental foci in the above-mentioned severely ill patient.

Table 3. Sensitivity, Specificity and Accuracy for detection of chronic periapical periodontitis in different radiological modalities. Numbers approximated based on (150-158).

Imaging modality	Sensitivity	Specificity	Accuracy
Histology as reference	- (ref.)	- (ref.)	- (ref.)
Panoramic view	~25 %	100 %	~50 %
Periapical film	~70 %	99 %	~75 %
Cone Beam Computed Tomography	~90 %	100 %	~90 %

Table 4 outlines, depending on the indication of the screening for dental foci, if a missed focus might be acceptable or not. In less critical situations, such as a dental screening indicated due to an upcoming chemotherapy or orthopedic surgery, for example, an artificial joint replacement or even organ transplantation (163), CBCT is only recommended in cases that cannot be clarified by thorough clinical examination in addition to conventional two-dimensional imaging comprising of a panoramic view and additional periapical radiographs for the root-canal filled teeth. This recommendation goes along with the rules for any general dental patient (153, 164). However, there are patients, with whom missing an occult dental focus (even if it may have silently pre-existed for years) is not an option. Such situations are found, for example, in patients receiving radiotherapy (with the corresponding focus in the radiation field) or in patients receiving high-dose IV antiresorptive therapy with bisphosphonates or monoclonal antibodies, which are associated with the development of osteonecrosis of the jaw (MRONJ) (165). However, one must be aware that these patients regularly have **pre-existing 3D-image datasets** (mostly MDCT), which can and should be utilized. Recently, several anti-VEGF (Vascular Endothelial Growth Factor Inhibitors) based antiangiogenic drugs and the anti-TKI (Tyrosine Kinase Inhibitors) as well as different types of immunomodulators have also been identified as potential promoters of MRONJ (166). In these patients, there is a relevant risk for severe complications due to a dental focus. In addition, future treatment options are severely limited due to permanent (even though local) immunodeficiency induced by the upcoming treatment. For these special indications, we strongly recommend considering CBCT screening for all nonvital teeth to achieve maximum sensitivity (Table 3).

Table 4: Different indications for dental focus screening require different levels of sensitivity due to differences in potential harm caused by missed foci.

Indication for dental screening	Need of CBCT	Substantiation / Assessment for case of missed focus
No special indication; general patient in routine dental control	Low	- Low risk for severe problems - Unlimited future treatment options
Prior to artificial joint or other foreign body (pacemaker) implantation	Low	- Low risk for medium severe problems - Unlimited future treatment options
Prior to chemotherapy	Medium	- Medium risk for medium severe problems - Temporary and relative immunodeficiency - Temporary and partially limited treatment options
Prior to organ transplantation	Medium	- Low risk but for excessive problem - Incomplete and decreasing but permanent immunodeficiency - Partially but permanently limited treatment options
Prior to heart valve surgery	Medium	- Potential risk for severe problems - Unlimited future treatment options
Before and during antiresorptive therapy (bisphosphonates, monoclonal antibodies) Not with the same level of evidence but also in a number of anti-VEGF based antiangiogenic drugs, anti-TKI and different types of immunomodulators (166) Eguia et al.	High	- Risk for excessive problem - Detection of subclinical early stages of MRONJ - Non-permanent but long-lasting local immunodeficiency - Limited treatment options
Prior to radiotherapy	Very high	- High risk for excessive problem - Permanent and pronounced local immunodeficiency - Severely limited future treatment options

In summary, CBCT is a cost-effective and dose-effective imaging modality for the diagnostic assessment of foci, especially in chronic periapical periodontitis. Mostly it is reserved for special cases where clinical observation and conventional, two-dimensional radiography cannot provide the necessary information. Such indications comprise cases with clinical signs but lack of (two-dimensional) radiological signs; anatomically complex lesions, close relationship to maxillary sinus or if molars are affected (153, 164). However, in special situations with the risk of severe consequences of a missed dental focus, mostly a periapical process, CBCT is justified as a standard imaging technique. As in many cases where extensive imaging modalities are considered, a referral to a specialist might be the smarter decision, and in line with dose protection considerations.

Conclusion: The final decision regarding the adequate imaging needed resides with the clinician performing the treatment. He will perform CBCT in any case, where clinic and conventional radiographs don’t add up and, in all cases, where no focus should be missed.

Endodontic infections and apical surgery (approved by all authors)

Prior to apical surgery, three-dimensional imaging can be considered if sufficient root canal treatment and coronal seal as prerequisites are fulfilled (167). Due to the complex anatomy of the teeth and alveolar process, standard intraoral radiographs regularly fail to adequately display roots and root canals due to distortion and overlap of anatomical landmarks (168-170). This is especially true for premolars and molars, which regularly superimpose with the maxillary sinus or the mandibular canal. Periapical lesions of maxillary molars often expand to the maxillary sinus and may induce sinus pathologies, which can best be assessed by three-dimensional scans. Furthermore, measuring the distance of the apex to the sinus floor or the mandibular canal is helpful to plan the surgery accurately (171-173). Also, superimposition between upper central incisor and incisive canal is an issue to address.

CBCT often reveals chronic periapical inflammation, and it also provides detailed information of a possible furcation involvement. This is relevant to treatment decision but justified only if invasive therapies are planned, for example, if the decision is between tooth removal or apical surgery to save the tooth (174, 175). For diagnostic purposes, persistent symptoms or pain without evident pathology in clinical examination and standard radiographs justify the use of CBCT (150, 171), which is well known to be superior in identification of periapical bone pathologies (151-158, 176). These and other diagnostic indications are outlined in the corresponding chapter of this communication (“Application of CBCT for the assessment and detection of dental foci”). CBCT scans indicated within the background of apical surgery should ideally be performed with a reduced field of view and patient related factors in choosing the ideal parameters (176). While in direct postoperative control often the same imaging technique as preoperatively is applied, during long-term follow-up, intraoral radiographs are usually sufficient in combination with a thorough clinical examination to assess success or failure of apical surgeries. CBCT scans can be used in selected cases of doubts regarding the bony healing following surgery (177).

In conclusion, Table 5 sums up the SADMFR-recommendations for the use of CBCT in the context of apical surgery.

Table 5. General recommendations of the SADMFR for the use of CBCT prior to apical surgery.

CBCT indicated	**CBCT not indicated**
- Prior to apical surgery of upper Molars - Prior to apical surgery of lower molars with difficult anatomy or pathology - Suspected periapical problem without periapical pathology in standard radiographs - Sensitive anatomical structures near the apex (E.g., maxillary sinus, mandibular canal, mental foramen, incisive canal) - Difficult pathology (E.g., involvement of root furcation)	- Insufficient root canal treatment - Insufficient coronal seal - Simple anatomy and pathology with no relevant structures nearby - Clinical signs of root fracture

Zusammenfassung

Einleitung

Seit ihrer Einführung in die Zahnmedizin vor rund 20 Jahren hat sich die Digitale Volumentomografie (DVT) zunehmend verbreitet. Vor zehn Jahren erfolgte die Erstveröffentlichung der Schweizerischen Konsensusleitlinien zur Anwendung der DVT im zahnmedizinischen Fachgebiet. Seither haben sich sowohl die DVT-Technik als auch deren zahnmedizinische Indikationen deutlich weiterentwickelt. Aus diesen Gründen wurde eine Überprüfung und Überarbeitung der Leitlinien durch die Schweizerischen Gesellschaft für Dentomaxillofaziale Radiologie SGDMFR initiiert.

Material und Methoden

Für die Überarbeitung der Leitlinien wurde eine Konsensgruppe gebildet. Diese unterteilte sich in eine Kerngruppe (Autoren), welche für den gesamten Prozess verantwortlich war. Die «approval»-Gruppe hingegen war für spezifische klinische Fragen und Teilkapitel zuständig und hat die jeweils zugeordneten Themenfelder gegengelesen und wo nötig korrigiert beziehungsweise ergänzt.

Resultate

Das Manuskript legt die überarbeiteten Leitlinien auf praktische Weise dar und ist entsprechend den unterschiedlichen Fachgebieten und klinischen Bereichen der Zahnmedizin gegliedert Im Ergebnis wurden die Leitlinien für die Bereiche rekonstruktive Zahnheilkunde, Kieferorthopädie, geriatrische Zahnheilkunde, Kiefergelenkserkrankungen, Kiefertraumatologie, gutartige und bösartige Tumore, Beurteilung und Erkennung von Zahnherden und periapikale / endodontische Entzündungen sowie apikale Chirurgie aktualisiert.

Diskussion

Insgesamt lässt sich feststellen, dass die DVT in der Zahnmedizin konsequenter und auch breiter eingesetzt wird als noch vor zehn Jahren. Sie ist gut etabliert und hat nachweislich Vorteile, sofern sie genau indiziert und vollständig analysiert wird. In den vergangenen Jahren konnte sie sich in der zahnärztlichen Radiologie mehr und mehr durchsetzen. In Teilbereichen beziehungsweise bei spezifischen Fragestellungen ist sie heute zahnärztlich-radiologischer «Gold Standard».

Résumé

Introduction

Depuis son introduction en médecine dentaire il y a une vingtaine d'années, la tomographie volumique à faisceau conique (TVFC), nommée en anglais *cone beam computed tomography* (CBCT) s'est de plus en plus répandue. Il y a dix ans, les résultats de la première conférence de consensus suisses sur l'utilisation de la TVFC dans le domaine de la médecine dentaire ont été publiés. Depuis, la technique de la TVFC et ses indications en médecine dentaire ont considérablement évolué, justifiant, un nouvel examen et une révision des directives ce qui a été initiés par la Société Suisse de Radiologie Dentaire et Maxillo-Faciale (SSRDMF).

Matériel et méthodes

Pour la révision des lignes directrices, un groupe de consensus a été constitué. Celui-ci s'est scindé en un groupe de travail principal (auteurs), responsable de l'ensemble du processus, et un groupe de validation. Ce dernier a abordé des questions cliniques spécifiques et pris en charge des chapitres dédiés. En outre, le groupe de validation a relu, complété et corrigé, si nécessaire, les sections textuelles traitant les thématiques attribuées.

Résultats

Le manuscrit présente les lignes directrices révisées de manière pratique et est structuré selon les différentes spécialités et domaines cliniques de la médecine dentaire. Les mises à jour des lignes directrices ont été effectuées pour la médecine dentaire reconstructive, l'orthodontie, la gérodontologie, les troubles de l'articulation temporo-mandibulaire, la traumatologie maxillaire, les tumeurs bénignes et malignes, l'évaluation et l'identification des foyers dentaires et des inflammations périapicales / endodontiques et de la chirurgie apicale.

Discussion

Dans l'ensemble, on constate que la TVFC est utilisée de manière plus conséquente et plus répandue en médecine dentaire qu'il y a dix ans. Elle est bien établie et présente des avantages avérés, sous condition d'une indication précise et d'une analyse complète. Ces dernières années, la TVFC s'est progressivement imposée en radiologie dentaire, devenant même la référence absolue dans certains domaines pour des questions spécifiques.

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References

1. Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volumetric CT machine for dental imaging based on the cone-beam technique: preliminary results. Eur Radiol. 1998;8(9):1558-64.
2. Eyrich G, Seifert B, Matthews F, et al. 3-Dimensional imaging for lower third molars: is there an implication for surgical removal? J Oral Maxillofac Surg. 2011;69(7):1867-72.
3. Lubbers HT, Matthews F, Damerau G, et al. Anatomy of impacted lower third molars evaluated by computerized tomography: is there an indication for 3-dimensional imaging? Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011;111(5):547-50.
4. Lübbers H-T, Kruse A, Obwegeser J, Grätz K, Eyrich G. Oblique High Resolution Tomography: The Ideal Plane for Visualization of the Gonial Section of the Mandibular Canal and its Related Structures? Journal of Healthcare Engineering. 2012;3(1):87-104.
5. Lubbers HT, Matthews F, Damerau G, et al. No plane is the best one-the volume is! Oral surgery, oral medicine, oral pathology and oral radiology. 2012;113(3):421.
6. Bornstein MM, Horner K, Jacobs R. Use of cone beam computed tomography in implant dentistry: current concepts, indications and limitations for clinical practice and research. Periodontol 2000. 2017;73(1):51-72.
7. Bornstein MM, Scarfe WC, Vaughn VM, Jacobs R. Cone beam computed tomography in implant dentistry: a systematic review focusing on guidelines, indications, and radiation dose risks. Int J Oral Maxillofac Implants. 2014;29 Suppl:55-77.
8. Harris D, Horner K, Grondahl K, et al. E.A.O. guidelines for the use of diagnostic imaging in implant dentistry 2011. A consensus workshop organized by the European Association for Osseointegration at the Medical University of Warsaw. Clin Oral Implants Res. 2012;23(11):1243-53.
9. Jacobs R, Salmon B, Codari M, Hassan B, Bornstein MM. Cone beam computed tomography in implant dentistry: recommendations for clinical use. BMC Oral Health. 2018;18(1):88.
10. Dula K, Benic GI, Bornstein M, et al. SADMFR Guidelines for the Use of Cone-Beam Computed Tomography/Digital Volume Tomography. Swiss dental journal. 2015;125(9):945-53.
11. Dula K, Bornstein MM, Buser D, et al. SADMFR guidelines for the use of Cone-Beam Computed Tomography/ Digital Volume Tomography. Swiss dental journal. 2014;124(11):1169-83.
12. Scarfe WC, Farman AG. What is cone-beam CT and how does it work? Dent Clin North Am. 2008;52(4):707-30, v.
13. Dagassan- Berndt D. Grundlagen zur Anwendung der Digitalen Volumentomographie. In: Lubbers HT, Dula K, editors. Digitale Volumentomographie. Berlin: Springer; 2021.
14. Pauwels R, Araki K, Siewerdsen JH, Thongvigitmanee SS. Technical aspects of dental CBCT: state of the art. Dentomaxillofac Radiol. 2015;44(1):20140224.
15. Lennon S, Patel S, Foschi F, Wilson R, Davies J, Mannocci F. Diagnostic accuracy of limited-volume cone-beam computed tomography in the detection of periapical bone loss: 360 degrees scans versus 180 degrees scans. Int Endod J. 2011;44(12):1118-27.
16. Costa EDD, Queiroz PM, Santaella GM, Capelozza ALA, Ambrosano GMB, Freitas DQ. Influence of scan mode (partial/full rotations) and FOV size in the formation of artefacts in cone beam CT. Dentomaxillofac Radiol. 2019;48(4):20180340.
17. Dula K, Jacobs R, Pauwels R, Salmon B, Costa Oenning AC. Indikationsstellung zur Digitalen Volumentomographie. In: Lubbers HT, Dula K, editors. Digitale Volumentomographie. Berlin: Springer; 2021.
18. European Commission: Directorate-General for Energy. Cone beam CT for dental and maxillofacial radiology: evidence-based guidelines. Publications Office; 2012.
19. Pauwels R, Faruangsaeng T, Charoenkarn T, Ngonphloy N, Panmekiate S. Effect of exposure parameters and voxel size on bone structure analysis in CBCT. Dentomaxillofac Radiol. 2015;44(8):20150078.
20. Hung K, Hui L, Yeung AWK, Scarfe WC, Bornstein MM. Image retake rates of cone beam computed tomography in a dental institution. Clin Oral Investig. 2020;24(12):4501-10.
21. Spin-Neto R, Wenzel A. Patient movement and motion artefacts in cone beam computed tomography of the dentomaxillofacial region: a systematic literature review. Oral Surg Oral Med Oral Pathol Oral Radiol. 2016;121(4):425-33.

22. Commission E, Energy D-Gf, Transport. European guidelines on radiation protection in dental radiology : the safe use of radiographs in dental practice: Publications Office; 2015.
23. Schulze R, Heil U, Gross D, et al. Artefacts in CBCT: a review. Dentomaxillofac Radiol. 2011;40(5):265-73.
24. Sancho-Puchades M, Hammerle CH, Benic GI. In vitro assessment of artifacts induced by titanium, titanium-zirconium and zirconium dioxide implants in cone-beam computed tomography. Clin Oral Implants Res. 2015;26(10):1222-8.
25. Queiroz PM, Santaella GM, Groppo FC, Freitas DQ. Metal artifact production and reduction in CBCT with different numbers of basis images. Imaging Sci Dent. 2018;48(1):41-4.
26. Vasconcelos KF, Codari M, Queiroz PM, et al. The performance of metal artifact reduction algorithms in cone beam computed tomography images considering the effects of materials, metal positions, and fields of view. Oral Surg Oral Med Oral Pathol Oral Radiol. 2019;127(1):71-6.
27. Flugge T, Derksen W, Te Poel J, Hassan B, Nelson K, Wismeijer D. Registration of cone beam computed tomography data and intraoral surface scans - A prerequisite for guided implant surgery with CAD/CAM drilling guides. Clin Oral Implants Res. 2017;28(9):1113-8.
28. Shujaat S, Bornstein MM, Price JB, Jacobs R. Integration of imaging modalities in digital dental workflows - possibilities, limitations, and potential future developments. Dentomaxillofac Radiol. 2021;50(7):20210268.
29. Abdelkarim A, Jerrold L. Clinical considerations and potential liability associated with the use of ionizing radiation in orthodontics. Am J Orthod Dentofacial Orthop. 2018;154(1):15-25.
30. Patcas R. Digitale Volumentomographie zur Diagnostik in der Kieferorthopädie. In: Lubbers HT, Dula K, editors. Digitale Volumentomographie. Berlin: Springer; 2021.
31. Bookstein FL. Reconsidering "The inappropriateness of conventional cephalometrics". Am J Orthod Dentofacial Orthop. 2016;149(6):784-97.
32. Moyers RE, Bookstein FL. The inappropriateness of conventional cephalometrics. Am J Orthod. 1979;75(6):599-617.
33. Ahlqvist J, Eliasson S, Welander U. The effect of projection errors on cephalometric length measurements. Eur J Orthod. 1986;8(3):141-8.
34. Scarfe WC, Azevedo B, Toghyani S, Farman AG. Cone Beam Computed Tomographic imaging in orthodontics. Aust Dent J. 2017;62 Suppl 1:33-50.
35. Signorelli L, Patcas R, Peltomaki T, Schatzle M. Radiation dose of cone-beam computed tomography compared to conventional radiographs in orthodontics. J Orofac Orthop. 2016;77(1):9-15.
36. Theodorakou C, Walker A, Horner K, et al. Estimation of paediatric organ and effective doses from dental cone beam CT using anthropomorphic phantoms. Br J Radiol. 2012;85(1010):153-60.
37. Yeh JK, Chen CH. Estimated radiation risk of cancer from dental cone-beam computed tomography imaging in orthodontics patients. BMC Oral Health. 2018;18(1):131.
38. Lee KS, Nam OH, Kim GT, Choi SC, Choi YS, Hwang EH. Radiation dosimetry analyses of radiographic imaging systems used for orthodontic treatment: comparison among child, adolescent, and adult patients. Oral Radiol. 2021;37(2):245-50.
39. De Grauwe A, Ayaz I, Shujaat S, et al. CBCT in orthodontics: a systematic review on justification of CBCT in a paediatric population prior to orthodontic treatment. Eur J Orthod. 2019;41(4):381-9.
40. Abdelkarim A. Cone-Beam Computed Tomography in Orthodontics. Dent J (Basel). 2019;7(3).
41. Samandara A, Papageorgiou SN, Ioannidou-Marathiotou I, Kavvadia-Tsatala S, Papadopoulos MA. Evaluation of orthodontically induced external root resorption following orthodontic treatment using cone beam computed tomography (CBCT): a systematic review and meta-analysis. Eur J Orthod. 2019;41(1):67-79.
42. Eslami E, Barkhordar H, Abramovitch K, Kim J, Masoud MI. Cone-beam computed tomography vs conventional radiography in visualization of maxillary impacted-canine localization: A systematic review of comparative studies. Am J Orthod Dentofacial Orthop. 2017;151(2):248-58.
43. Li Y, Deng S, Mei L, et al. Accuracy of alveolar bone height and thickness measurements in cone beam computed tomography: a systematic review and meta-analysis. Oral Surg Oral Med Oral Pathol Oral Radiol. 2019;128(6):667-79.

44. Tilen R, Patcas R, Bornstein MM, Ludwig B, Schatzle M. The nasopalatine canal, a limiting factor for temporary anchorage devices: a cone beam computed tomography data study. Eur J Orthod. 2017;39(6):646-53.
45. Camps-Pereperez I, Guijarro-Martinez R, Peiro-Guijarro MA, Hernandez-Alfaro F. The value of cone beam computed tomography imaging in surgically assisted rapid palatal expansion: a systematic review of the literature. Int J Oral Maxillofac Surg. 2017;46(7):827-38.
46. Yousefi F, Rafiei E, Mahdian M, Mollabashi V, Saboonchi SS, Hosseini SM. Comparison Efficiency of Posteroanterior Cephalometry and Cone-beam Computed Tomography in Detecting Craniofacial Asymmetry: A Systematic Review. Contemp Clin Dent. 2019;10(2):358-71.
47. Sawchuk D, Currie K, Vich ML, Palomo JM, Flores-Mir C. Diagnostic methods for assessing maxillary skeletal and dental transverse deficiencies: A systematic review. Korean J Orthod. 2016;46(5):331-42.
48. Stasiak M, Wojtaszek-Slominska A, Racka-Pilszak B. Current methods for secondary alveolar bone grafting assessment in cleft lip and palate patients - A systematic review. J Craniomaxillofac Surg. 2019;47(4):578-85.
49. Zimmerman JN, Lee J, Pliska BT. Reliability of upper pharyngeal airway assessment using dental CBCT: a systematic review. Eur J Orthod. 2017;39(5):489-96.
50. van Vlijmen OJ, Kuijpers MA, Berge SJ, et al. Evidence supporting the use of cone-beam computed tomography in orthodontics. J Am Dent Assoc. 2012;143(3):241-52.
51. Savoldi F, Dagassan-Berndt D, Patcas R, et al. The use of CBCT in orthodontics with special focus on upper airway analysis in patients with sleep-disordered breathing. Dentomaxillofac Radiol. 2024;53(3):178-88.
52. Radic J, Patcas R, Stadlinger B, Wiedemeier D, Rucker M, Giacomelli-Hiestand B. Do we need CBCTs for sufficient diagnostics?-dentist-related factors. Int J Implant Dent. 2018;4(1):37.
53. Karlo CA, Patcas R, Kau T, et al. MRI of the temporo-mandibular joint: which sequence is best suited to assess the cortical bone of the mandibular condyle? A cadaveric study using micro-CT as the standard of reference. Eur Radiol. 2012;22(7):1579-85.
54. Markic G, Muller L, Patcas R, et al. Assessing the length of the mandibular ramus and the condylar process: a comparison of OPG, CBCT, CT, MRI, and lateral cephalometric measurements. Eur J Orthod. 2015;37(1):13-21.
55. Bernini JM, Kellenberger CJ, Eichenberger M, Eliades T, Papageorgiou SN, Patcas R. Quantitative analysis of facial asymmetry based on three-dimensional photography: a valuable indicator for asymmetrical temporomandibular joint affection in juvenile idiopathic arthritis patients? Pediatr Rheumatol Online J. 2020;18(1):10.
56. Oenning AC, Pauwels R, Stratis A, et al. Halve the dose while maintaining image quality in paediatric Cone Beam CT. Sci Rep. 2019;9(1):5521.
57. Ettinger RL, Beck JD. Geriatric dentistry: is there such a discipline? Aust Dent J. 1984;29(6):355-61.
58. Ettinger RL, Beck JD. Geriatric dental curriculum and the needs of the elderly. Spec Care Dentist. 1984;4(5):207-13.
59. Mathews JD, Forsythe AV, Brady Z, et al. Cancer risk in 680,000 people exposed to computed tomography scans in childhood or adolescence: data linkage study of 11 million Australians. BMJ. 2013;346:f2360.
60. Pierce DA, Shimizu Y, Preston DL, Vaeth M, Mabuchi K. Studies of the mortality of atomic bomb survivors. Report 12, Part I. Cancer: 1950-1990. Radiat Res. 1996;146(1):1-27.
61. Pearce MS, Salotti JA, Little MP, et al. Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours: a retrospective cohort study. Lancet. 2012;380(9840):499-505.
62. Marine PM, Stabin MG, Fernald MJ, Brill AB. Changes in radiation dose with variations in human anatomy: larger and smaller normal-stature adults. J Nucl Med. 2010;51(5):806-11.
63. Brenner DJ, Hall EJ. Cancer risks from CT scans: now we have data, what next? Radiology. 2012;265(2):330-1.
64. De Felice F, Di Carlo G, Saccucci M, Tombolini V, Polimeni A. Dental Cone Beam Computed Tomography in Children: Clinical Effectiveness and Cancer Risk due to Radiation Exposure. Oncology. 2019;96(4):173-8.
65. Brody AS, Frush DP, Huda W, Brent RL, American Academy of Pediatrics Section on R. Radiation risk to children from computed tomography. Pediatrics. 2007;120(3):677-82.

66. Pauwels R, Jacobs R, Dula K, Lubbers HT. Strahlenbelastung und Strahlenschutz bei der Digitalen Volumentomographie. In: Lubbers HT, Dula K, editors. Digitale Volumentomographie. Berlin: Springer; 2021.
67. Walter C, Berg BI. Digitale Volumentomographie zur Diagnostik von Entzündungen der Kieferknochen. In: Lubbers HT, Dula K, editors. Digitale Volumentomographie. Berlin: Springer; 2021.
68. Neuhaus KW, Krastl G, Kuhl S, et al. Digitale Volumentomographie zur Diagnostik von pathologischen Befunden der Zähne. In: Lubbers HT, Dula K, editors. Digitale Volumentomographie. Berlin: Springer; 2021.
69. Schimmel M, Muller F, Suter V, Buser D. Implants for elderly patients. Periodontol 2000. 2017;73(1):228-40.
70. Sun Y, Luebbers HT, Agbaje JO, et al. Accuracy of Dental Implant Placement Using CBCT-Derived Mucosa-Supported Stereolithographic Template. Clinical implant dentistry and related research. 2015;17(5):862-70.
71. Rostetter C, Sailer I, Fehmer V. Digitale Volumentomographie zur Diagnostik in der oralen Implantatologie. In: Lubbers HT, Dula K, editors. Digitale Volumentomographie. Berlin: Springer; 2021.
72. Dumbuya A, Gomes AF, Marchini L, Zeng E, Comnick CL, Melo SLS. Bone changes in the temporomandibular joints of older adults: A cone-beam computed tomography study. Spec Care Dentist. 2020;40(1):84-9.
73. Pretzl C, Lubbers HT, Gratz KW, Kruse AL. [Metastases in the temporomandibular joint: a review from 1954 to 2013. Rare causes for temporomandibular disorders]. Swiss dental journal. 2014;124(10):1067-83.
74. Kruse AL, Luebbers HT, Obwegeser JA, Edelmann L, Graetz KW. Temporomandibular disorders associated with metastases to the temporomandibular joint: a review of the literature and 3 additional cases. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010;110(2):e21-8.
75. Pretzl C, Lubbers HT, Gratz KW, Kruse AL. [CASE REPORT: TMJ-like symptoms as first sign of a tumorous disease]. Swiss dental journal. 2015;125(10):1107-14.
76. Filo K, Schneider T, Kruse AL, Locher M, Gratz KW, Lubbers HT. Frequency and anatomy of the retromolar canal - implications for the dental practice. Swiss dental journal. 2015;125(3):278-92.
77. Schriber M, Lubbers HT. Digitale Volumentomographie zur Diagnostik retinierter Zähne. In: Lubbers HT, Dula K, editors. Digitale Volumentomographie. Berlin: Springer; 2021.
78. de Castro JGK, Carvalho BF, de Melo NS, et al. A new cone-beam computed tomography-driven index for osteoporosis prediction. Clin Oral Investig. 2020;24(9):3193-202.
79. Metzler P, Zemann W, Lübbers H-T, et al. Bone mineral density measurements performed by cone-beam computed tomography in the bisphosphonate-related osteonecrosis-affected jaw. Oral Radiology. 2012;28(2):101-8.
80. Rostetter C, Metzler P, Schenkel JS, Seifert B, Luebbers HT. Comparison of in vivo cone-beam and multidetector computed tomographic scans by three-dimensional merging software. The British journal of oral & maxillofacial surgery. 2015;53(10):1021-6.
81. Mawani F, Lam EW, Heo G, McKee I, Raboud DW, Major PW. Condylar shape analysis using panoramic radiography units and conventional tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2005;99(3):341-8.
82. Barghan S, Merrill R, Tetradis S. Cone beam computed tomography imaging in the evaluation of the temporomandibular joint. J Calif Dent Assoc. 2010;38(1):33-9.
83. Honey OB, Scarfe WC, Hilgers MJ, et al. Accuracy of cone-beam computed tomography imaging of the temporomandibular joint: comparisons with panoramic radiology and linear tomography. Am J Orthod Dentofacial Orthop. 2007;132(4):429-38.
84. Hilgenberg-Sydney PB, Bonotto DV, Stechman-Neto J, et al. Diagnostic validity of CT to assess degenerative temporomandibular joint disease: a systematic review. Dentomaxillofac Radiol. 2018;47(5):20170389.
85. Ma RH, Yin S, Li G. The detection accuracy of cone beam CT for osseous defects of the temporomandibular joint: a systematic review and meta-analysis. Sci Rep. 2016;6:34714.
86. Alexiou K, Stamatakis H, Tsiklakis K. Evaluation of the severity of temporomandibular joint osteoarthritic changes related to age using cone beam computed tomography. Dentomaxillofac Radiol. 2009;38(3):141-7.

87. Alkhader M, Ohbayashi N, Tetsumura A, et al. Diagnostic performance of magnetic resonance imaging for detecting osseous abnormalities of the temporomandibular joint and its correlation with cone beam computed tomography. Dentomaxillofac Radiol. 2010;39(5):270-6.
88. Kaeppler G. Applications of cone beam computed tomography in dental and oral medicine. Int J Comput Dent. 2010;13(3):203-19.
89. Hechler BL, Phero JA, Van Mater H, Matthews NS. Ultrasound versus magnetic resonance imaging of the temporomandibular joint in juvenile idiopathic arthritis: a systematic review. Int J Oral Maxillofac Surg. 2018;47(1):83-9.
90. Petersson A. What you can and cannot see in TMJ imaging--an overview related to the RDC/TMD diagnostic system. J Oral Rehabil. 2010;37(10):771-8.
91. Crow HC, Parks E, Campbell JH, Stucki DS, Daggy J. The utility of panoramic radiography in temporomandibular joint assessment. Dentomaxillofac Radiol. 2005;34(2):91-5.
92. Schmitter M, Gabbert O, Ohlmann B, et al. Assessment of the reliability and validity of panoramic imaging for assessment of mandibular condyle morphology using both MRI and clinical examination as the gold standard. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2006;102(2):220-4.
93. Hara GF, de Souza-Pinto GN, Brasil DM, et al. What is the image appearance of juvenile idiopathic arthritis in MRI, CT, and CBCT of TMJ? A systematic review. Clin Oral Investig. 2023;27(5):2321-33.
94. Larheim TA, Abrahamsson AK, Kristensen M, Arvidsson LZ. Temporomandibular joint diagnostics using CBCT. Dentomaxillofac Radiol. 2015;44(1):20140235.
95. Shintaku WH, Venturin JS, Azevedo B, Noujeim M. Applications of cone-beam computed tomography in fractures of the maxillofacial complex. Dent Traumatol. 2009;25(4):358-66.
96. Brisco J, Fuller K, Lee N, Andrew D. Cone beam computed tomography for imaging orbital trauma--image quality and radiation dose compared with conventional multislice computed tomography. Br J Oral Maxillofac Surg. 2014;52(1):76-80.
97. Gellrich NC, Diebler J. Digitale Volumentomographie zur Diagnostik bei Schädeltraumata. In: Lubbers HT, Dula K, editors. Digitale Volumentomographie. Berlin: Springer; 2021.
98. Schoen R, Fakler O, Metzger MC, Weyer N, Schmelzeisen R. Preliminary functional results of endoscope-assisted transoral treatment of displaced bilateral condylar mandible fractures. Int J Oral Maxillofac Surg. 2008;37(2):111-6.
99. Pohlenz P, Blessmann M, Blake F, Heinrich S, Schmelzle R, Heiland M. Clinical indications and perspectives for intraoperative cone-beam computed tomography in oral and maxillofacial surgery. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007;103(3):412-7.
100. Pohlenz P, Blessmann M, Blake F, Gbara A, Schmelzle R, Heiland M. Major mandibular surgical procedures as an indication for intraoperative imaging. J Oral Maxillofac Surg. 2008;66(2):324-9.
101. Zizelmann C, Gellrich NC, Metzger MC, Schoen R, Schmelzeisen R, Schramm A. Computer-assisted reconstruction of orbital floor based on cone beam tomography. Br J Oral Maxillofac Surg. 2007;45(1):79-80.
102. Drage NA, Sivarajasingam V. The use of cone beam computed tomography in the management of isolated orbital floor fractures. Br J Oral Maxillofac Surg. 2009;47(1):65-6.
103. Blumer M, Gander T, Kruse Gujer A, Seifert B, Rucker M, Lubbers HT. Influence of Mirrored Computed Tomograms on Decision-Making for Revising Surgically Treated Orbital Floor Fractures. Journal of oral and maxillofacial surgery : official journal of the American Association of Oral and Maxillofacial Surgeons. 2015;73(10):1982 e1-9.
104. Blumer M, Kumalic S, Gander T, et al. Retrospective analysis of 471 surgically treated zygomaticomaxillary complex fractures. Journal of cranio-maxillo-facial surgery : official publication of the European Association for Cranio-Maxillo-Facial Surgery. 2018;46(2):269-73.
105. Stuehmer C, Essig H, Bormann KH, Majdani O, Gellrich NC, Rucker M. Cone beam CT imaging of airgun injuries to the craniomaxillofacial region. Int J Oral Maxillofac Surg. 2008;37(10):903-6.
106. Eggers G, Welzel T, Mukhamadiev D, Wortche R, Hassfeld S, Muhling J. X-ray-based volumetric imaging of foreign bodies: a comparison of computed tomography and digital volume tomography. J Oral Maxillofac Surg. 2007;65(9):1880-5.
107. Grobe A, Weber C, Schmelzle R, Heiland M, Klatt J, Pohlenz P. The use of navigation (BrainLAB Vector vision(2)) and intraoperative 3D imaging system (Siemens Arcadis Orbic 3D) in the treatment of gunshot wounds of the maxillofacial region. Oral Maxillofac Surg. 2009;13(3):153-8.

108. Sadiq Z, Bisase B, Coombes DM. Use of cone beam computed tomography in the management of glass injuries to the face. Br J Oral Maxillofac Surg. 2010;48(4):308-9.
109. Luebbers HT, Zemann W, Kruse AL, Graetz KW. A simple technique for sterility and patient accessibility during intraoperative three-dimensional (3D) imaging. The British journal of oral & maxillofacial surgery. 2013;51(8):e312-3.
110. Lubbers HT, Matthews F, Kruse AL. [Modern technologies in cranio-maxillofacial surgery]. Praxis (Bern 1994). 2014;103(5):257-64.
111. Lubbers HT, Jacobsen C, Matthews F, Gratz KW, Kruse A, Obwegeser JA. Surgical navigation in craniomaxillofacial surgery: expensive toy or useful tool? A classification of different indications. J Oral Maxillofac Surg. 2011;69(1):300-8.
112. Lubbers HT, Matthews F, Zemann W, Gratz KW, Obwegeser JA, Bredell M. Registration for computer-navigated surgery in edentulous patients: a problem-based decision concept. J Craniomaxillofac Surg. 2011;39(6):453-8.
113. Lubbers HT, Obwegeser JA, Matthews F, Eyrich G, Gratz KW, Kruse A. A simple and flexible concept for computer-navigated surgery of the mandible. J Oral Maxillofac Surg. 2011;69(3):924-30.
114. Luebbers HT, Messmer P, Obwegeser JA, et al. Comparison of different registration methods for surgical navigation in cranio-maxillofacial surgery. J Craniomaxillofac Surg. 2008;36(2):109-16.
115. Bettschart C, Kruse A, Matthews F, et al. Point-to-point registration with mandibulo-maxillary splint in open and closed jaw position. Evaluation of registration accuracy for computer-aided surgery of the mandible. J Craniomaxillofac Surg. 2012;40(7):592-8.
116. Venosta D, Sun Y, Matthews F, et al. Evaluation of two dental registration-splint techniques for surgical navigation in cranio-maxillofacial surgery. Journal of cranio-maxillo-facial surgery : official publication of the European Association for Cranio-Maxillo-Facial Surgery. 2014;42(5):448-53.
117. Sun Y, Luebbers HT, Agbaje JO, et al. Validation of anatomical landmarks-based registration for image-guided surgery: an in-vitro study. Journal of cranio-maxillo-facial surgery : official publication of the European Association for Cranio-Maxillo-Facial Surgery. 2013;41(6):522-6.
118. Sun Y, Luebbers HT, Agbaje JO, et al. Evaluation of 3 different registration techniques in image-guided bimaxillary surgery. J Craniofac Surg. 2013;24(4):1095-9.
119. Quereshy FA, Savell TA, Palomo JM. Applications of cone beam computed tomography in the practice of oral and maxillofacial surgery. J Oral Maxillofac Surg. 2008;66(4):791-6.
120. Fernandes R, DiPasquale J. Computer-aided surgery using 3D rendering of maxillofacial pathology and trauma. Int J Med Robot. 2007;3(3):203-6.
121. Alimohammadi R. Imaging of Dentoalveolar and Jaw Trauma. Radiol Clin North Am. 2018;56(1):105-24.
122. Meara DJ. Diagnostic Imaging of the Maxillofacial Trauma Patient. Atlas Oral Maxillofac Surg Clin North Am. 2019;27(2):119-26.
123. Rozema R, Doff MH, van Ooijen PM, et al. Diagnostic reliability of low dose multidetector CT and cone beam CT in maxillofacial trauma-an experimental blinded and randomized study. Dentomaxillofac Radiol. 2018;47(8):20170423.
124. Dreizin D, Nam AJ, Hirsch J, Bernstein MP. New and emerging patient-centered CT imaging and image-guided treatment paradigms for maxillofacial trauma. Emerg Radiol. 2018;25(5):533-45.
125. Burian E, Sollmann N, Ritschl LM, et al. High resolution MRI for quantitative assessment of inferior alveolar nerve impairment in course of mandible fractures: an imaging feasibility study. Sci Rep. 2020;10(1):11566.
126. MacDonald D. Lesions of the jaws presenting as radiolucencies on cone-beam CT. Clin Radiol. 2016;71(10):972-85.
127. Yeung AWK, Jacobs R, Bornstein MM. Novel low-dose protocols using cone beam computed tomography in dental medicine: a review focusing on indications, limitations, and future possibilities. Clin Oral Investig. 2019;23(6):2573-81.
128. Vanhoenacker FM, Bosmans F, Vanhoenacker C, Bernaerts A. Imaging of Mixed and Radiopaque Jaw Lesions. Semin Musculoskelet Radiol. 2020;24(5):558-69.
129. Bali A, Vanhoenacker FM, Vanhoenacker C, Bernaerts A. Imaging of Radiolucent Jaw Lesions. Semin Musculoskelet Radiol. 2020;24(5):549-57.

130. Reichart PA, Dula K, Baumhoer D, Gratz K, Lubbers HT. Digitale Volumentomographie zur Diagnostik bei Tumoren. In: Lubbers HT, Dula K, editors. Digitale Volumentomography. Berlin: Springer; 2021.
131. Nakagawa Y, Kobayashi K, Ishii H, et al. Preoperative application of limited cone beam computerized tomography as an assessment tool before minor oral surgery. Int J Oral Maxillofac Surg. 2002;31(3):322-6.
132. Kumar J, Vanagundi R, Manchanda A, Mohanty S, Meher R. Radiolucent Jaw Lesions: Imaging Approach. Indian J Radiol Imaging. 2021;31(1):224-36.
133. Wang Z, Zhang S, Pu Y, Wang Y, Lin Z, Wang Z. Accuracy of cone-beam computed tomography for the evaluation of mandible invasion by oral squamous cell carcinoma. BMC Oral Health. 2021;21(1):226.
134. Ivashchenko O, Pouw B, de Witt JK, et al. Intraoperative verification of resection margins of maxillary malignancies by cone-beam computed tomography. Br J Oral Maxillofac Surg. 2019;57(2):174-81.
135. Closmann JJ, Schmidt BL. The use of cone beam computed tomography as an aid in evaluating and treatment planning for mandibular cancer. J Oral Maxillofac Surg. 2007;65(4):766-71.
136. Momin MA, Okochi K, Watanabe H, et al. Diagnostic accuracy of cone-beam CT in the assessment of mandibular invasion of lower gingival carcinoma: comparison with conventional panoramic radiography. Eur J Radiol. 2009;72(1):75-81.
137. Bornstein MM, Andreoni C, Meier T, Leung YY. Squamous Cell Carcinoma of the Gingiva Mimicking Periodontal Disease: A Diagnostic Challenge and Therapeutic Dilemma. Int J Periodontics Restorative Dent. 2018;38(2):253-9.
138. Rocha TG, Feitosa EF, Maiolino A, et al. Imaginological characterization of multiple myeloma lesions of the jaws through cone-beam computed tomography. Oral Radiol. 2020;36(2):168-76.
139. Ziegler CM, Woertche R, Brief J, Hassfeld S. Clinical indications for digital volume tomography in oral and maxillofacial surgery. Dentomaxillofac Radiol. 2002;31(2):126-30.
140. Osman SO, de Boer HC, Astreinidou E, Gangsaas A, Heijmen BJ, Levendag PC. On-line cone beam CT image guidance for vocal cord tumor targeting. Radiother Oncol. 2009;93(1):8-13.
141. Xu F, Wang J, Bai S, et al. Detection of intrafractional tumour position error in radiotherapy utilizing cone beam computed tomography. Radiother Oncol. 2008;89(3):311-9.
142. Bratel J, Kennergren C, Dernevik L, Hakeberg M. Treatment of oral infections prior to heart valve surgery does not improve long-term survival. Swed Dent J. 2011;35(2):49-55.
143. Guzzi G. Medicine forgets dentistry. Lancet. 2005;366(9489):894; author reply
144. Keulers BJ, Roumen RH, Keulers MJ, Vandermeeren L, Bekke JP. Bilateral groin pain from a rotten molar. Lancet. 2005;366(9479):94.
145. Gander T, Dagassan-Berndt D, Mascolo L, Kruse AL, Gratz KW, Lubbers HT. [Facial pain- a rare cause. Impacted lower third molars causing primarily "unclear" facial pain: a case report]. Schweizer Monatsschrift fur Zahnmedizin = Revue mensuelle suisse d'odonto-stomatologie = Rivista mensile svizzera di odontologia e stomatologia / SSO. 2013;123(9):767-77.
146. Dief S, Veitz-Keenan A, Amintavakoli N, McGowan R. A systematic review on incidental findings in cone beam computed tomography (CBCT) scans. Dentomaxillofac Radiol. 2019;48(7):20180396.
147. Togan B, Gander T, Lanzer M, Martin R, Lubbers HT. Incidence and frequency of nondental incidental findings on cone-beam computed tomography. Journal of cranio-maxillo-facial surgery : official publication of the European Association for Cranio-Maxillo-Facial Surgery. 2016;44(9):1373-80.
148. Waring E, Mawardi H, Woo SB, et al. Evaluation of a community-based dental screening program prior to radiotherapy for head and neck cancer: a single-center experience. Support Care Cancer. 2019;27(9):3331-6.
149. Margalit DN, Losi SM, Tishler RB, et al. Ensuring head and neck oncology patients receive recommended pretreatment dental evaluations. J Oncol Pract. 2015;11(2):151-4.
150. Low KM, Dula K, Burgin W, von Arx T. Comparison of periapical radiography and limited cone-beam tomography in posterior maxillary teeth referred for apical surgery. J Endod. 2008;34(5):557-62.
151. Estrela C, Bueno MR, Leles CR, Azevedo B, Azevedo JR. Accuracy of cone beam computed tomography and panoramic and periapical radiography for detection of apical periodontitis. J Endod. 2008;34(3):273-9.
152. de Paula-Silva FW, Wu MK, Leonardo MR, da Silva LA, Wesselink PR. Accuracy of periapical radiography and cone-beam computed tomography scans in diagnosing apical periodontitis using histopathological findings as a gold standard. J Endod. 2009;35(7):1009-12.

153. Maddalone M, Bonfanti E, Pellegatta A, Citterio CL, Baldoni M. Digital Orthopantomography vs Cone Beam Computed Tomography-Part 1: Detection of Periapical Lesions. J Contemp Dent Pract. 2019;20(5):593-7.
154. Bonfanti E, Maddalone M, Pellegatta A, Citterio CL, Baldoni M. Digital Orthopantomography vs Cone Beam Computed Tomography-Part 2: A CBCT Analysis of Factors Influencing the Prevalence of Periapical Lesions. J Contemp Dent Pract. 2019;20(6):664-9.
155. Lo Giudice R, Nicita F, Puleio F, et al. Accuracy of Periapical Radiography and CBCT in Endodontic Evaluation. Int J Dent. 2018;2018:2514243.
156. Koc C, Sonmez G, Yilmaz F, Karahan S, Kamburoglu K. Comparison of the accuracy of periapical radiography with CBCT taken at 3 different voxel sizes in detecting simulated endodontic complications: an ex vivo study. Dentomaxillofac Radiol. 2018;47(4):20170399.
157. Sakhdari S, Talaeipour AR, Talaeipour M, Pazhutan M, Tehrani SH, Kharazifard MJ. Diagnostic Accuracy of CBCT with Different Voxel Sizes and Intraoral Digital Radiography for Detection of Periapical Bone Lesions: An Ex-Vivo Study. J Dent (Tehran). 2016;13(2):77-84.
158. Shahbazian M, Vandewoude C, Wyatt J, Jacobs R. Comparative assessment of periapical radiography and CBCT imaging for radiodiagnostics in the posterior maxilla. Odontology. 2015;103(1):97-104.
159. Wang S, Xu Y, Shen Z, et al. The Extent of the Crack on Artificial Simulation Models with CBCT and Periapical Radiography. PLoS One. 2017;12(1):e0169150.
160. Patel S, Brady E, Wilson R, Brown J, Mannocci F. The detection of vertical root fractures in root filled teeth with periapical radiographs and CBCT scans. Int Endod J. 2013;46(12):1140-52.
161. Kobayashi-Velasco S, Salineiro FC, Gialain IO, Cavalcanti MG. Diagnosis of alveolar and root fractures: an in vitro study comparing CBCT imaging with periapical radiographs. J Appl Oral Sci. 2017;25(2):227-33.
162. Rechenberg DK, Kruse A, Gratz KW, Attin T, Lubbers HT. [Chronic orofacial pain (OFP) of different origin. A case report]. Schweiz Monatsschr Zahnmed. 2011;121(9):839-48.
163. Schenkel JS, Muller N, Rostetter C, Gander T, Lubbers HT. [The organ transplanted patient in the dental clinic]. Swiss Dent J. 2017;127(10):884-6.
164. Horner K. Radiation Protection: Cone Beam CT for Dental and Maxillofacial Radiology. Evidence based guidelines 2011 [v2.0 Final:[Available from: www.sedentexct.eu.
165. Lübbers HT. Bisphosphonate und andere antiresorptive Medikamente. Relevante Aspekte für den zahnärztlichen Praxisalltag. Dental Tribune. 2017(1):10-1.
166. Eguia A, Bagan-Debon L, Cardona F. Review and update on drugs related to the development of osteonecrosis of the jaw. Med Oral Patol Oral Cir Bucal. 2020;25(1):e71-e83.
167. von Arx T, Penarrocha M, Jensen S. Prognostic factors in apical surgery with root-end filling: a meta-analysis. J Endod. 2010;36(6):957-73.
168. Ioannidis K, Lambrianidis T, Beltes P, Besi E, Malliari M. Endodontic management and cone-beam computed tomography evaluation of seven maxillary and mandibular molars with single roots and single canals in a patient. J Endod. 2011;37(1):103-9.
169. Kfir A, Telishevsky-Strauss Y, Leitner A, Metzger Z. The diagnosis and conservative treatment of a complex type 3 dens invaginatus using cone beam computed tomography (CBCT) and 3D plastic models. Int Endod J. 2013;46(3):275-88.
170. Uraba S, Ebihara A, Komatsu K, Ohbayashi N, Okiji T. Ability of Cone-beam Computed Tomography to Detect Periapical Lesions That Were Not Detected by Periapical Radiography: A Retrospective Assessment According to Tooth Group. J Endod. 2016;42(8):1186-90.
171. Bornstein MM, Lauber R, Sendi P, von Arx T. Comparison of periapical radiography and limited cone-beam computed tomography in mandibular molars for analysis of anatomical landmarks before apical surgery. J Endod. 2011;37(2):151-7.
172. Bornstein MM, Wasmer J, Sendi P, Janner SF, Buser D, von Arx T. Characteristics and dimensions of the Schneiderian membrane and apical bone in maxillary molars referred for apical surgery: a comparative radiographic analysis using limited cone beam computed tomography. J Endod. 2012;38(1):51-7.
173. von Arx T, Kach S, Suter VGA, Bornstein MM. Perforation of the maxillary sinus floor during apical surgery of maxillary molars: A retrospective analysis using cone beam computed tomography. Aust Endod J. 2020;46(2):176-83.

174. Walter C, Weiger R, Dietrich T, Lang NP, Zitzmann NU. Does three-dimensional imaging offer a financial benefit for treating maxillary molars with furcation involvement? A pilot clinical case series. Clin Oral Implants Res. 2012;23(3):351-8.
175. Walter C, Weiger R, Zitzmann NU. Accuracy of three-dimensional imaging in assessing maxillary molar furcation involvement. J Clin Periodontol. 2010;37(5):436-41.
176. Ramis-Alario A, Soto-Penaloza D, Tarazona-Alvarez B, Penarrocha-Diago M, Penarrocha-Oltra D. Comparison of the diagnostic efficacy of 2D radiography and cone beam computed tomography in persistent apical periodontal disease: A PRISMA-DTA systematic review and meta-analysis. Oral Surg Oral Med Oral Pathol Oral Radiol. 2021;132(4):e153-e68.
177. von Arx T, Janner SF, Hanni S, Bornstein MM. Evaluation of New Cone-beam Computed Tomographic Criteria for Radiographic Healing Evaluation after Apical Surgery: Assessment of Repeatability and Reproducibility. J Endod. 2016;42(2):236-42.