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Cone Beam Computed Tomography in Implant Dentistry: Current Recommendations for Clinical Use

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Abstract

Introduction

CBCT imaging is a well-established radiographic modality in treatment planning for dental implants, becoming increasingly popular and globally used in oral health care. This is partially due to new insights into anatomic landmarks, and structures at risk during implant placement such as neurovascular structures. Another reason for the growing use of CBCT scanning is the increasing popularity of computer-guided surgery that relies on digital planning based on high-quality CBCT images but may also include the superimposition of intraoral scans and extraoral face scans to create a 3D virtual dental patient.

Material and Methods

In order to find the relevant literature included in this article, an electronic search of MEDLINE (PubMed) database was performed. This literature search included studies published in English language published prior to December 2022.

Results

CBCT imaging is a well-established radiographic modality in treatment planning for dental implants, becoming increasingly popular and globally used in oral health care. This is partially due to new insights into anatomic landmarks, and structures at risk during implant placement such as neurovascular structures. Another reason for the growing use of CBCT scanning is the increasing popularity of computer-guided surgery that relies on digital planning based on high-quality CBCT images but may also include the superimposition of intraoral scans and extraoral face scans to create a 3D virtual dental patient.

Conclusion

CBCT imaging is a well-established radiographic modality in treatment planning for dental implants, which is due to new insights into anatomic landmarks, and structures at risk during implant placement. Another reason for the growing use of CBCT scanning is the increasing popularity of computer-guided surgery that relies on digital planning based on high-quality CBCT images but may also include the superimposition of intraoral and extraoral face scans to create a 3D virtual patient. The use of CBCT imaging following insertion of dental implants should be restricted to specific post-operative complications (such as iatrogenic neurovascular trauma), required implant retrieval and follow-up of complex surgical procedures.

Keywords: Cone beam computed tomography, Dental implants, Presurgical planning, Guidelines, Radiation dose, Virtual patient.

Introduction

Since the first CBCT device was introduced in the late nineties (NewTom 9000, QR, Verona) with the initial scientific reports dating back from 1998 (2, 20), CBCT has become popular for a wide range of applications in recent years. Although the areas of application are limited to hard tissue diagnostics, CBCT is well established in the entire dental, oral - and maxillofacial specialties. With more than 40 device types from 20 manufacturers, produced in seven countries (10) the term CBCT describes very different devices. They are very inhomogeneous in terms of their technical structure, which also applies to the objective image quality of the different devices applies (26). The smallest imaging volumes (Field of View: FOV) are 4 cm in diameter and 3.7 cm in height, the largest at 24 cm in diameter and 23 cm in height (21;10). With regard to the radiation exposure, CBCT devices are also very different; so, in regard to this feature, they can hardly be regarded as a device class (27).

Three-dimensional X-ray imaging compared to traditional, two-dimensional methods offers the fundamental advantage of the naturally occurring three-dimensionality to reproduce anatomical structures without loss of dimensions. Contrary to two-dimensional X-ray, where the information in the direction of the beam path (only as a summation image pictured) is greatly reduced, enabling three-dimensional X-rays, e.g. CBCT, the representation of the depicted anatomical structures in all spatial directions. This leads to an increased directional information content of three-dimensional images. The spatial allocation of anatomical structures is often only possible in three dimensions. For many clinical issues, however, there is still no evidence as to the extent to which these additional information leads to an increased diagnostic benefit or a clinical advantage for the patients.

Compared to adults, children and adolescents have a disproportionately high inherent risk of radiation damage (3,12,19). Because of their lower height and volume children receive a higher dose with the same exposure parameters (16,17). These reasons implicate particularly strict indication for this group of people. Research results in terms of indications for CBCT in children are limited. So far, no indication-oriented and patient-specific protocols for CBCT have been developed. In the available publications often inconsistent and inadequate recommendations for reducing radiation doses in children and young people have been published (1, 15, 22).

Objective

The aim of the present state-of-the-art paper is to present a narrative review providing support for the hypothesis on using CBCT for oral implant planning and to attempt formulating recommendations for justified and optimized CBCT imaging in order to integrate the evidence found in the literature with the needs of the clinician.

Material and Methods

In order to find the relevant literature included in this article, an electronic search of MEDLINE (PubMed) database was performed. This literature search included studies published in English language or with an English language abstract published.

Review, Results and Discussion

Before each implant insertion, a clinical and radiological diagnosis of the implant bed is required. This should enable a qualitative and quantitative assessment of the bone supply as well as the adjacent anatomical structures, which in all spatial directions without dimension loss can be mapped and analyzed (14;37).

Three-dimensional imaging techniques are used in complex surgical Interventions superior to two-dimensional methods (35). An indication for three-dimensional imaging procedures can already primarily exist after anamnesis and clinical examination, under the condition that there is a significant anatomical deviation from the norm. Further indications can occur if after orienting two-dimensional diagnostics a detailed spatial assessment of the anatomical structures and the pathological changes in the tooth, mouth and jaw area (e.g. cysts, neoplasia, odontogenic processes, osteopathies) is necessary. If the necessary diagnostic information for therapy decision and in special cases for follow-up controls cannot be obtained from the classic two-dimensional imaging, three-dimensional diagnostics is clearly indicated.

Three-dimensional imaging offers advantages in avoiding injuries to important anatomical structures, such as the nerve canals of the incisive nerve (38) and in the mandible those of the inferior alveolar nerve and its anterior loop (8, 23). Since the representation in CBCT is as good as in the medical grade CT (21), therefore, for implant planning, CBCT should be used instead of medical grade CT scans (6).

Due to the lower average exposure to radiation, CBCT is given the preference in implant planning. Under an evidence-based assessment, that the clinical benefit through the three-dimensional imaging obtains additional information, the overall outcome of the implant treatment is unclear.

Currently, in terms of image quality, any imaging methods should be given general preference. A superiority of one of the two procedure (2D- vs 3D) in the context of implantology has not yet been proven. There are currently no randomized or controlled patient trials demonstrating the usefulness of a three-dimensional diagnostics regarding the quality of the surgical result and/or the frequency of complications in implant dentistry. The implantologist should be aware of the CBCT related increased radiation exposure versus the two-dimensional imaging. This applies in particular to young patients. Possibilities of limiting the FOV and thus the radiation exposure should be explored when used. Technical limitations can lead to a restricted indication.

To what extent a CBCT scan can be used for the peri-implantitis diagnostics, against the background of the immediate vicinity of the implant image in the light of well-known existing imaging errors, based on the current scientific data, cannot be clarified with certainty. Therefore, the diagnosis of the immediate peri-implant osseous environment (e.g osseointegration of a dental implant) is only possible to a limited extent due to artefacts in the CBCT and the CT (9,30).

Linear measurement sections, as typically performed in implant treatment planning, show maximum relative errors between 3% and 8% in the CBCT (31, 32, 36). This means for measuring distance of a typical implant length of 10 mm there is a possible inaccuracy of approximately 0.3-0.8mm.

For virtual surgical implant planning and also for intraoperative supportive procedures or as part of the prefabrication of abutments and superstructures, a three-dimensional X-ray diagnosis is required. Computer-aided (static) implantation with the help of surgical templates represents an additional option for prosthetic oriented implantation, especially in complex cases and with minimally invasive procedures (6).

In a systematic review (33) for computer-assisted implantation in an evaluation of a total of 1465 implants revealed a mean deviation of the implant apex position from the planned position of 1.3 mm and a maximum deviation of 7.1 mm. Regarding the angular deviations a total of 1845 implants had an average deviation of 3.9° and a maximum deviation calculated from the planning position of 21.1° (33, 34).

The gray values shown in CBCT scans are not standardized, which is different from the standardization when using the Hounsfield scale values in a medial grade CT. Therefore, between different devices a quantitative use of the gray values in CBCT recordings, for example for bone density estimation, is not possible (7). However, there is evidence that instead of a purely density-based bone density estimate, a structural analysis of the bone based on a CBCT is possible (24 25). The integration of all 3D information (model surface scans, implant models, CBCT data sets, etc.) in the planning and therapy of dental implants in the sense of a virtual patients represent a current goal to improve patient-specific implant rehabilitation (18). The CBCT is also suitable for the planning of other, image-based manufactured, patient-specific implants and CAD-CAM titanium-meshes (28).

Conclusion

Before inserting an implant, a clinical examination and adequate radiological diagnosis of the implant bed is required. If the information required for diagnostics, treatment decisions and implementation, and in special cases for follow-up checks, cannot be obtained from the clinical examination and/or two-dimensional imaging, three-dimensional diagnostics should be carried out. This also recommended if the success after an augmentation procedure is uncertain.

A CBCT may also be indicated in the case of clear anatomical peculiarities in the implantation area, such as severely undercut alveolar processes, severe alveolar process atrophy or maxillary sinus septa recognizable in a panoramic image. A CBCT may also be indicated for specific surgical and/or prosthetic therapy concepts such as immediate implantation, immediate restoration, navigation-assisted implantology, complex interdisciplinary therapy concepts. The CBCT should be, due to very variable and by different parameters influenced, non-standardized gray values, not used for quantitative determination of the bone density based on the gray values.

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