CONE BEAM COMPUTED TOMOGRAPHY IN IMPLANT DENTISTRY

KOMPJUTERIZOVANA TOMOGRAFIJA KONUSNOG ZRAKA U ORALNOJ IMPLANTOLOGIJI

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Summary

Introduction. Cone beam computed tomography is the most reliable procedure in diagnostic radiology; it is of great importance in the prevention of complications and in improving the treatment outcome. Therefore, it is necessary to use it in the phases of preparation, implementation and verification of the therapy results. As part of the standard pre-implant procedure, this current technique is irreplaceable for making treatment plans regarding surgical performance and postoperative monitoring of patients. The emphasis is on precise planning of implant therapy and prevention of possible complications.

Strengths and limitations of the cone beam computed tomography. Maxillofacial diagnosis used to be limited to the conventional two-dimensional radiography or to the multislice computed tomography, both providing an insight into the third dimension, but with a high dose of radiation. Using the cone beam technology, possibilities for a wide range of three-dimensional diagnosis have been created. Computed tomography provides sophisticated, high resolution visualization of bone architecture while reducing the radiation dose. Cone beam computed tomography in implant dentistry. This three-dimensional technique has a special importance in implant dentistry. The main characteristic of the cone beam computed tomography images is precise distinction of details, where the spatial relations between anatomical structures and their topography are clearly defined. The tomographic images enable measuring the density, buccal alveolar bone height of every part of the jaw, visualization of pathological structures and bone sloping, as well as all anatomical structures. Conclusion. Nowadays, implant dentistry is impossible without using the cone beam computed tomography, computer softwares, and series of programs focused on analysis, planning, virtual placement of implants in the desired position and all the other processes necessary for dental implementation. Cone beam computed tomography diagnosis is considered to be the best diagnostic method because, of all the three-dimensional imaging techniques, it has the highest diagnostic value and low level of radiation exposure.

Key words: Dental Implantation; Cone-Beam Computed Tomography; Imaging, Three-Dimensional; Planning Techniques; Diagnosis

Sažetak


Prednosti i ograničenja tehnike kompjuterizovane tomografije konusnih zraka. Diagnostička maksiološko-afalne regije bila je ograničena na konvencionalnu dvodimenzionalnu radiografiju ili na snimke multislajsne kompjuterizovane tomografije koji su pružali uvid u treću dimenziju, ali sa visokom dozom zračenja. Primenom tehnologije konusnih zraka stvorene su mogućnosti širokog spektra primene trodimenzionalne dijagnostike. Tomografizovana tomografija omogućava sofisticiranu vizualizaciju koštane arhitekture sa visokom rezolucijom i smanjenom dozom zračenja. Tehnika kompjuterizovane tomografije konusnih zraka u implantologiji. Glavna karakteristika tomografskih snimaka jeste precizno razlikovanje detalja, gde su jasno definisani prostorni odnosi anatomske strukture i njihova topografija. Tomografska snimanja omogućavaju merenje gustine, visine i bukolingvalnog promera alveolarne kosti svakog dela vilice, te vizualizaciju patologije, nagiba kosti, kao i druge anatomske strukture. Zaključak. Danas dentalna implantologija nije moguća bez korišćenja tomografskih uređaja i programskih podrška računara u vidu niza programa usmerenih na analizu, planiranje, virtualnu ugradnju implantata u željeni položaj i svih ostalih procesa koji su neophodni za sprovođenje terapije. Tomografska dijagnostika se smatra najboljim dijagnostičkim postupkom zato što, od svih trodimenzionalnih sistema, daje najveće dijagnostičke vrednosti emitiujući najmanju dozu zračenja.

Ključne reči: oralna implantologija; kompjuterizovana tomografija konusnog zraka; 3D imidžing; planiranje; dijagnoza

Abbreviations

2D – two-dimensional
3D – three-dimensional
CBCT – cone beam computed tomography
FBCT – fan beam computed tomography
DVT – digital volume tomography
FOV – field of view
DICOM – digital imaging and communications in medicine

disadvantages (deformation, poor resolution, zooming, etc.) and limitations while interpreting soft and bone tissues. Therefore, they are replaced by more recent, advanced radiographic methods, such as computed tomography. Cone Beam Computed Tomography (CBCT) is an advanced radiographic method that provides increased spatial resolution, reduced radiation exposure, smaller interpretation area, cheaper appliances, etc. The use of CBCT in dentistry is growing exponentially, due to increased spatial resolution, reduced radiation exposure, smaller interpretation area, cheaper appliances, etc.

Cone Beam Computed Tomography

Cone Beam Computed Tomography is an advanced digital recording technique that allows the operator to generate multiplanar “slices” and to reconstruct a 3D image of the target area using rotating conical X-ray through a series of mathematical algorithms (Figure 1). Mozzo introduced CBCT technology in 1998, and a new form of 3D evolution was established [1]. Several studies showed that CBCT technology makes high quality and precise cross-sectional images with a relatively low exposure to radiation [2]. The use of CBCT in dentistry is growing exponentially, due to increased production of equipment and a growing acceptance of this recording technique. The size of the field of view (FOV) describes the scan volume of CBCT scanning machines and depends on the size of the detector, its shape, beam projection geometry and possibilities of beam focusing, which may differ from manufacturer to manufacturer. Collimation width of ionizing radiation is limited to the recording target area, due to which the exposition is lower, and the FOV is selected specifically for each case. In general, based on the size of the FOV, CBCT units can be classified into small, medium and large volume units. Small volume CBCT machines are used to scan sextants or quadrants of one jaw only. They usually provide higher image resolution since the X-ray scattering (noise) is reduced, as well as the FOV. Medium volume CBCT machines are used to scan both jaws, while large FOV equipment allows visualization of the entire head [3]. The main limitation of the large FOV CBCT units is the size of the field exposed to radiation. If the selected voxel size is minimal, devices with large FOV have reduced image resolution compared with intraoral radiographs or with images recorded on small FOV CBCT devices with inherently small size of voxels [4]. Curtailing the volume should be based on the clinician’s evaluation of a particular situation. For the purposes of implant placement, small and medium FOV are suitable to visualize the desired area. CBCT equipment with a small volume provides several advantages over the CBCT equipment with a large volume: increased spatial resolution, reduced radiation exposure, smaller interpretation area, cheaper appliances, etc.

Features:

- Fast scanning: acquisitions in 10 – 20 sec, complete 3D image reconstruction in less than a minute
- Small form factor (117 cm (46”) x 137 cm (54”), suitable for installation even in the smallest offices
- FOV – 16 cm x 13 cm to 16 cm x 21 cm in extended FOV mode
- High resolution; voxel sizes down to 100 microns with a focal spot of 0.5 mm
- Digital flat rate detector is incomparably superior to image intensifier and transmits the lowest doses of radiation, that do not increase over time
- The highest efficiency in its class allows minimal radiation dose
- 14 bit sensor provides 16,384 shades of gray in favor of a better contrast
- Image processing protocols with extremely low radiation dose
- X-ray tube with a fixed anode has low maintenance costs and long service life
Advantages and limitations of CBCT

Cone Beam Computed Tomography imaging provides direct visualization of the dental status, including 3D images of the maxillofacial skeleton, compared to 2D imaging that provides insight in only 2 dimensions. The ability to visualize a complete geometrical shape of the target region, avoiding superposition and planar observation, allows accurate radiological interpretation without any assumptions [5]. Significance of this recording combined with 3D optical input model has the potential to reduce the percentage of mistakes in implant placing. However, the quality of the interpretation is based on the evaluation skills and thoroughness of the diagnostician, on using native and independent treatment planning softwares, and on determination of the appropriate FOV for each particular case (Figure 2). There are several manufacturers of CBCT machines in dental radiology. This has led to significant variability in radiation dosage, scanning, facilitated utilization, image resolution and software dynamics among the CBCT appliances.

The most significant limitations of CBCT devices are the lack of accurate presentation of the soft tissue internal structure, limited correlation between Hounsfield units for standardized quantification of bone density, and different types of artifacts arising mainly from metal restorations that can interfere with the diagnostic process by masking the underlying structure [6]. In order to improve visualization of the gingival soft tissue contour and thickness, it is necessary to place cotton rolls or separate the lip from the buccal cavity by air.

The highest aspects of available software applications include their ease of navigation, costs, quantity and quality of available diagnostic tools, and implant planning modules. By application of advanced softwares, waste impacts or artifact can be significantly reduced, all in order to enhance the accuracy of diagnosis and reduce the limitations of this type of recording.

Cone Beam Computed Tomography technique in implant dentistry

The use of 3D data in the field of diagnostics and treatment planning has been improved through the availability of CBCT. Its implementation helps the clinicians to estimate the 3D anatomy of the area where the implant is to be placed. After collection and processing the data, the software reconstructs the CBCT information [7]. In order to meet prosthetic requirements it is necessary to choose an ideal location for the implant placement, defining the appropriate quality and volume of the bone where osteotomy can be performed, and a stable position for the implant provided. The 3D visualization and evaluation of the implant area structure is defined by planning phase analysis using the following parameters:

1. Assessment of the available bone (height, width, relative quality of the cortical and spongy parts)
2. Determination of the 3D topography of the alveolar ridge
3. Identification and localization of vital anatomical structures such as inferior alveolar nerve, mental foramen, maxillary sinus, floor of the nasal cavity, etc.
4. Potential tissue for implant placement evaluation
5. Fabrication of CBCT-derived implant surgical guides
6. Communication of the diagnostic treatment planning information to all implant team members
7. Evaluation of prosthetic/restorative possibilities via implant software applications
8. Evaluation of postoperative acceptance of implants

In addition, a CBCT scan, combined with software modeling, can be used as a platform for treatment planning and it can virtually simulate perfect placement of the implant defining the surgical, prosthetic and orthodontic conditions.

Discussion

There are about 30 different types of CBCT devices, so it is important to entirely conduct the research on the same device.

Implementation of the CBCT technique in implant dentistry is divided into 4 categories:

1. CBCT and diagnostics
Cone Beam Computed Tomography is an excellent diagnostic modality in oral implantology, which is used to assess the implant site, presence of pathological changes and foreign bodies, morphology and relation with the surrounding anatomical structures.

2. CBCT and implant planning
In dental implant planning, the CBCT technique is most frequently used in the linear measurement of
the ridge. CBCT images are reliable and show all the data on the amount of existing bone in the jaw for preoperative planning. The existence of metals, prosthetic restorations, does not affect the measurement accuracy of the CBCT images. Another advantage is the possibility of determining the topography of the ridge and the relation between the surrounding anatomical structures in all three dimensions. CBCT can accurately determine the thickness of the cortical bone (buccal, lingual and palatal), floor of the nasal cavity and maxillary sinus walls.

Evaluation of bone density is of great importance. It is proved that CBCT can determine distribution of trabecular bones, showing a high correlation with the primary stability of the implant. It identifies the blood vessels on the side walls of the maxillary sinus, which is necessary in cases of sinus augmentation. CBCT technique is of great importance to doctors in the prevention of postoperative complications.

3. CBCT and surgical guidance
In oral surgery, CBCT is divided into passive, semi-active and active.
- Passive CBCT provides information on linear measurements, relative bone quality, 3D ridge topography, and proximity of vital anatomical structures.
- Semi-active CBCT includes the use of imported data that simulate the virtual implant preceding the development of surgical guides being used during the implant placement. Selecting the site of implant placement is in accordance with the restorative needs and depends on the computer program protocol. A template should be made prior to the scanning.
- Active CBCT refers to the use of data for surgical navigation systems performing fully computer-guided implant placement.

4. CBCT and post-implant assessment
The presence of beam hardening and artifacts surrounding the implant in some cases may complicate the CBCT visualization of the bone-implant interface.

Conclusion
The decision whether to use Cone Beam Computed Tomography should be based on clinical history and examination. The benefits must exceed the risk of exposing the patient to ionizing radiation, especially when children are involved, and when a recording with a large field of view volume is necessary. Based on information obtained by three-dimensional imaging procedures, it is suggested that the Cone Beam Computed Tomography technique should be used as an imaging alternative in cases where bone augmentation is suspected, where conventional radiography may not be able to determine the structure in three dimensions as previously described:
- Computer guided implant planning and placement including navigation systems
- Placement of the implant in a highly esthetic zone
- Pre- and post-surgical evaluation of implant acceptance
- History or trauma to the jaws, foreign bodies, maxillofacial lesions, developmental anomalies, etc.
- Evaluation of post-implant complications.
It is important to bear in mind that the smallest possible field of view should be used, and that the entire image volume should be interpreted.

The use of Cone Beam Computed Tomography requires careful and proper handling and Cone Beam Computed Tomography scans help to improve the surgical accuracy, reduce postoperative morbidity, and are valuable in restorative phase of treatment.

References