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MICRO-CT IN DENTISTRY: A PARADIGM SHIFT IN RESEARCH

Dentistry

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ABSTRACT

Micro-CT is a non-destructive imaging tool used for production of high resolution 3 D images composed of 2 D trans-axial projections or slices of the target specimen. Due to these advantages, Micro-CT has been recommended as an advanced imaging tool in dental research for many applications such as endodontics, restorative dentistry, tissue engineering, implants assessment, and research on the mineral density of hard tissues and bone growth. This article describes about the components, working principle, uses, advantages and limitations of Micro CT.

KEYWORDS

CT, Dentistry, Endodontics, Micro-CT, Research

INTRODUCTION

Micro Computed Tomography (Micro-CT) is a tool that enables 3-dimensional imaging of an object with very high resolution. In this method, there is no need for sample preparation or slicing (1). Micro-CT is actually a high-resolution type of CT . It is a gold standard for enumerating the bone architecture. It is possible to examine the internal structure of tissue and the internal adaptation of materials to surfaces without destroying them (2). The spatial resolution of Micro-CT is 5-50 micrometre.

Lee Feldkamp developed the first micro-CT system in the early 1980s to evaluate structural defects in ceramic materials. It was in 1984 that Goldstein coined the term Micro CT (3). He was the first one to publish a study on Bone architecture using Micro-CT.

Components of MICRO CT

The various components of a micro-CT (3) are shown in Fig 1

1. X ray Source
2. Radiation filter
3. Collimator(This focusses the beam to fan/ cone beam projector)
4. X ray Detector
5. Specimen stand (stage)
6. Phosphor detector/ CCD Camera for image analysis

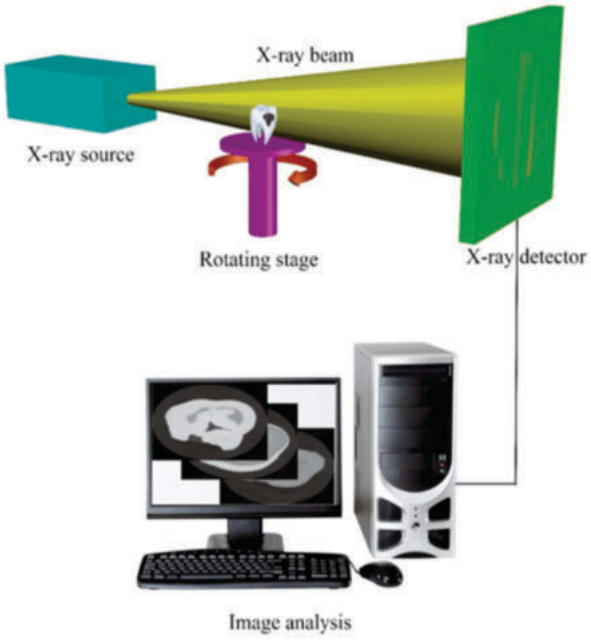

Fig 1: Pictorial Representation of Of Micro CT Imaging Set up.

Working Principle

The X ray source(micro-focus X ray tube) and detector are used to obtain the 2D images (4). The x ray beam used has electrons of 240 K voltage. Reconstruction of 2 D images to form 3D images is done using filtered back projection algorithm. Voxel of this 3 D image is 1 micrometre and this is 1 lakh times smaller than the one created by CT.

Types of Micro CT and Mechanism of Image Capturing

There are broadly 2 types of Micro CT viz. in-vitro Micro CT and in-vivo Micro CT.

In the in-vitro Micro CT, x ray source and detector are static while the object moves.(5). High spatial resolution images are formed in these machines(1-30 micrometre). In the in-vivo Micro CT, the object is static, while the x ray source and detector move. The spatial resolution is 30-100 micrometre. These machines produce faster images as compared to in-vitro Micro CT(6)

Applications of Micro CT

1. Evaluation of bone structure: Micro CT is used for detailed analysis of trabecular structure and cortical porosity. Bone mass and bone morphology in Maxilla , mandible and alveolar bone can be studied extensively using Micro CT (7). these scans can be used for the detailed study of osteoporosis and to evaluate the efficiency of anti-resorptive medicines.
2. Evaluation of soft tissue: For the evaluation of soft tissue a contrast media has to be usually used. When this technique is used for angiography (8), this is termed as Contrast Enhanced Micro CT Angiography. Micro CT is used for study of renal microvasculature and for visualisation of cervical spinal cord micro-vessels (using barium sulphate). Also it can be used to study tendons and ligaments in detail.

3. Diagnostic applications: Micro CT can be used to a great advantage in differential diagnosis of cyst and tumours. It can be used to study in detail the extent of tumours, Maxillofacial fractures, dentofacial fractures as well as root fractures (9). Various pathological lesions such as odontomas and Garre's osteomyelitis can also be studied extensively using Micro CT.

It has been well established that Micro CT is better than CT for detection of caries, tooth resorption, periodontal lesions and periapical lesions. Also root morphology can certainly be better evaluated using Micro CT and so is the assessment outcome of periodontal regenerative procedures.

4. Caries Exploration: Micro CT has the special ability to evaluate the mineral content changes in dental hard tissue. This can better detect the occlusal and proximal caries(10). The morphogenesis of carious lesion a s well as the demineralisation and remineralisation of the tooth can be studied far more precisely using a Micro CT.

Micro CT is also used to study the mineral density of white spot lesions and dentinal carious lesions, also the mineral concentration of the tooth can also be calculated effectively using the Micro CT (11).

5. Study of root canal morphology: Micro CT is the best tool to evaluate root canal morphology in detail (Fig 2). Both qualitative as well as quantitative analysis can be thoroughly done using this imaging technique(6). Micro CT can be used to study 3-dimensional change in the root canals before and after root canal preparation. Several features such as surface area, volume, amount of dentine removed during root canal preparation, canal curvature, canal dimensions etc. can be clearly visualized using Micro CT(12-15). One can also evaluate the post-space preparation and canal transportation using Micro CT.

Detailed imaging of small canals, isthmus, inter-canal connections, accessory canals, multiple apical foramens and C- shaped canals can be obtained using Micro CT.

Formation of cracks in the root canal dentine formed due to rotary endodontic instruments can also be clearly seen using the Micro CT. This imaging technique can also be used for the study of radicular grooves and to evaluate the porosity in the obturation or the voids in the filling materials.

6. Alveolar bone levels: Micro CT can be used to obtain the 3D images of the bone and thus the bone architecture as well as the bone trabecular pattern can be studied in detail(16). This imaging technique is also useful in the studies involving the bone tooth interface including the periodontal ligament.

7. Craniofacial skeletal development and structure: Micro CT can be used in the study of condyles and their porosity. This technique is also used to assess the bone levels in periodontitis(17).

8. Evaluation of dental implants: Micro CT is being used in the evaluation of bone information in the peri-implant region. It has also been used to study the stress concentration at bone-implant interface using Finite Element Analysis. Interestingly Micro CT has also been used to assess that how an implant surface texture may improve the Osseo-integration (18).

9. Tissue engineering: Micro CT has been used for the study of scaffolds and the study of characterization of scaffold architecture. This imaging technique helps in the assessment of cell attachment and cell proliferation in the science of tissue engineering (19).

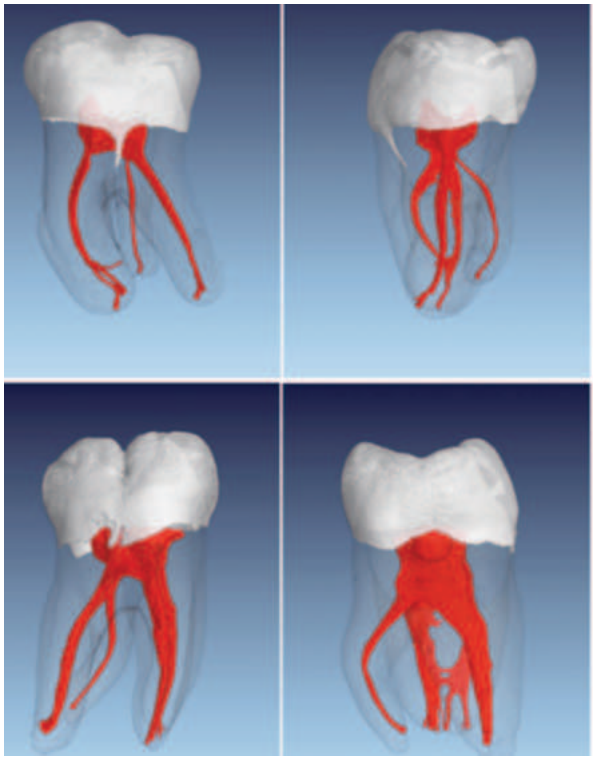

Fig 2: Detailed Morphology of Root Canal System of Mandibular Molars as seen in Micro CT (Picture Courtesy: A Guidebook to Molar Endodontics, ebrary.net)

Advantages of Micro CT

1. Micro CT provides high spatial resolution images.
2. Multiplanar reconstruction can be done using the Micro CT
3. Micro CT provides a high contrast resolution better than CBCT thereby allowing excellent discrimination of very small differences in the attenuation coefficient (< 1%)
4. Images of both hard tissue and soft tissue can be obtained.
5. The samples are not damaged during the imaging.
6. the measurements obtained during Micro CT are highly accurate.
7. This technique eliminates “Noise” during the imaging and thus provides better information.

Limitations of Micro CT

1. Micro CT is an expensive imaging technique, and the equipment is quite complicated.
2. The radiation dose is comparatively high when performing the Micro CT
3. So far, it is not much suitable for the patients and is limited only for in-vitro analysis
4. Beam hardening and Cupping artifacts as well as Scattering due to the presence of metallic objects is seen in Micro CT.
5. There's a long exposure time of radiation in this technique.
6. The image processing (scanning and reconstruction) also takes a long time therefore it is quite a time-consuming procedure.
7. There is a higher learning curve before one can use this equipment or use the concerned software for analysis of the images obtained.

Futuristic Approach

1. Synchroton Micro CT devices: These are better than the conventional Micro CT as they use the high intensity and monochromatic X-ray beam. the advantage of these devices is the higher resolution image obtained after the scan (20).
2. Nano CT Devices: These devices have a distinct advantage to enable visualization at a cellular level. The sub-micron hard tissue cracks can also be seen using these devices. The images obtained are of better resolution, are less blurred and have clear edges. Also, faster scans can be obtained using the Nano CT devices.

CONCLUSION

The potential of micro-CT as an emerging, accurate, non-destructive approach is clear, and the valuable research findings reported in the literature provide an impetus for researchers to perform future studies focusing on employing this method in dental research.

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