The possible usability of three-dimensional cone beam computed dental tomography in dental research

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Abstract. The innovations and advantages of three-dimensional cone beam computed dental tomography (3D CBCT) are continually growing for its potential use in dental research. Imaging techniques are important for planning research in dentistry. Newly improved 3D CBCT imaging systems and accessory computer programs have recently been proven effective for use in dental research. The aim of this study is to introduce 3D CBCT and open a window for future research possibilities that should be given attention in dental research.

1. Introduction

Imaging methods are quite important in terms of diagnosis, treatment, and research and can guide follow-up in dentistry. Introduced in 1996 for dentoalveolar imaging, cone beam computed tomography (CBCT) generates three-dimensional (3D) data at a lower cost and with lower absorbed doses of radiation than conventional CT [1]. Dental imaging techniques have advanced with the introduction of tomography, and the innovations and advantages of the 3D cone beam computed dental tomography (3D CBCT) are growing each day for its potential application and use in many areas of dental diagnosis and research [1]. 3D CBCT has made it possible to isolate areas of interest within the scope of a radiographic examination and research. Imaging techniques are crucial for planning research in dentistry. Newly improved 3D CBCT imaging systems and accessory computer programs have been effectively applied in dentistry and dental research over the last several decades. CBCT offers numerous advantages compared to traditional 2D radiography, including a lack of superimposition, 1:1 measurements, the absence of geometric distortions, and 3D display [1]. Different sections of images can be obtained with computer software from 3D CBCT image data. Due to the range of possibilities 3D CBCT has had wide applications in endodontic treatment, orthodontics, cranio-maxillofacial surgery, pediatric dentistry, prothetic treatment, and implantology [2]. The aim of this study is to introduce 3D CBCT and open windows for future research possibilities, which should be given attention in dental diagnosis, research, and education.

What is 3D CBCT?

3D CBCT is a special type of x-ray machine used in situations in which regular dental or facial x-rays are not sufficient. It is not used routinely because there is significantly more radiation exposure from
this scanner than regular dental x-rays [3] CBCT is not the same as conventional CT. However, 3D CBCT can be used to produce images that are similar to those produced by conventional CT imaging. With 3D CBCT, an x-ray beam in the shape of a cone is moved around the patient to produce a large number of images, also called views. 3D CBCT scans produce high-quality images. 3D CBCT is commonly useful for more complex cases that require treatment planning for orthodontic issues; cephalometric analysis; surgical planning for impacted teeth; the diagnosis of temporomandibular joint disorder (TMJ), the accurate placement of dental implants, the evaluation of the jaw, sinuses, nerve canals, and nasal cavity; detecting and measuring and treating jaw tumors; determining bone structure and tooth orientation, endodontic treatment, locating the origin of pain or pathology, reconstructive surgery, and moreover diagnosis in dentistry [4]. Other advantages of 3D CBCT are its low radiation dose, shorter scan time, low cost, ease of use, fewer image artifacts, beam limitation, and axial, sagittal, coronal, and multiplanar imaging because it allows interactive sections [5]. Dentists embrace 3D CBCT due to the search results and diagnostic information directly influencing clinical decisions. Accurate data lead to better treatment planning decisions and potentially more predictable outcomes. There are many different kinds of dental imaging systems. First, panoramic radiography plays an important role in the diagnosis, planning of dental implants, and determining of bone size and pathology. Second, periapical radiography/bitewing radiography is routinely used to examine of the areas that need more detailed imaging than panoramic radiographic images. Third, occlusal radiography can be used to gain information on the bucco-lingual width and contour in the edentulous mandible. However, the buccolingual width can not be determined precisely due to the irregular outer contour and does not provide any information about the vertical dimension of the jaw bone. Cephalometric radiography lateral, posterior-anterior, and oblique views of the jaws can be obtained with low distortion. It is important to note that all conventional dental imaging systems show magnification, superposition, and deviation (distortion); they are unavoidable in such systems. CBCT’s imaging technique is based on a cone-shaped X-ray beam that is centered on a 2D detector, which offers the advantages of a higher rate of acquisition. Thus, oral health professionals gain a highly accurate 3D image of the patient’s anatomy from a single scan with a lower radiation dose and occupying less space. A 3D CBCT beam is conical in shape, and a medical CT beam is a fan-shaped beam [5] (Figure 1).

![Figure 1. Beam types. (https://www.drkorwin.com/blog/cone-beam-ct)](https://www.drkorwin.com/blog/cone-beam-ct)
Field of view (FOV) can be chosen by the size of the desired area for review, displaying a higher resolution than can be achieved when working in small spaces. The effective radiation dose is lower at a smaller FOV. Moreover, the regions, with the exception of the certain limited certain areas, do not receive radiation [5,6] (Figure 2).

![Figure 2. Some FOV types. Only limited certain areas receive radiation](https://pocketdentistry.com/11-cone-beam-computed-tomography-volume-acquisition/)

The images are taken from the skull in 5–70 seconds, the length of time varies according to the product device and FOV size from 4 to 17 cm in height, from 15 to 18 cm in diameter, in a cylindrical volume area and with a selected cross-section range in the third plane [6].

Voxel size determines the clarity of images. Its name comes from two words: Voxel = Volume + Pixel (Figure 3). CBCT images have been made by voxels. The CBCT device determines the resolution of the image and creates a 3D set consisting of small cube-shaped structures known as voxels (Figure 4). When the voxel size decreases, the number of cubes in per unit area increases, and thereby the resolution and clearness of the image increase. However, the radiation exposure time increases, and thus the radiation dose patients take increases [6,7]. For dental applications, with 0.3 voxels in 8.9 seconds, 440 images can be obtained in three plane with CBCT, and, with 0.125 voxels in 26.9 seconds, 624
images can be obtained. However, most authors have emphasized that a 0.3 voxel size gives dental specialists sufficient images for diagnosis and treatment [7-9].

**Figure 4.** Axis in 3D; the physician can see 3D CBCT images from different sides.

There are many different kinds of CBCT devices produced by different manufacturers; when compared, it is clear that they have quite different features (Figure 5).

| Model                        | Type                  | Manufacturer                  | Position  | Voxels          |
|------------------------------|-----------------------|--------------------------------|-----------|-----------------|
| 3D Accuitomo                 | CBCT                  | J. Morita, Kyoto, Japan        | Zittend   | 0.125           |
| 3D Accuitomo FPD 170         | CBCT                  | J. Morita, Kyoto, Japan        | Zittend   | 0.08, 0.125, 0.160, 0.250 |
| 3D Accuitomo FPD 60          | CBCT                  | J. Morita, Kyoto, Japan        | Zittend   | 0.125           |
| 3D Accuitomo FPD 80          | CBCT                  | J. Morita, Kyoto, Japan        | Zittend   | 0.08, 0.125, 0.160 |
| Art 3D                       | Pano+CBCT+Ceph        | Oy Ajat, Espoo, Finland        | Staand    | NA              |
| Auge ZIO series (ZIO (CM), X ZIO (CM), ZIO Maxim) | CBCT (en/of Pano,Ceph opties) | Asahi Roentgen, Kyoto, Japan | Staand    | 0.1–0.15        |
| CB MercuRay                  | CBCT                  | Hitachi Medical Systems, Kyoto, Japan | Zittend | 0.1–0.4        |
| CB Throne                    | CBCT                  | Hitachi Medical Systems, Kyoto, Japan | Zittend | 0.1–0.4        |
| Digi-X 3D                    | Pano+CBCT             | Oy Ajat, Espoo, Finland        | Staand    | NA              |
| Galileos Comfort             | CBCT                  | Sirona Dental Systems GmbH, Bensheim Germany | Staand/Zittend | 0.15–0.30 |
| Galileos Compact             | CBCT                  | Sirona Dental Systems GmbH, Bensheim Germany | Staand/Zittend | 0.15 |
| Model | Type | Manufacturer | Position | Voxels |
|-------|------|--------------|----------|--------|
| GX-CB 500 (powered by I-CAT) | CBCT | Gendex/Kavo Dental GmbH, Bieberach, Germany | Zittend | 0.125–0.4 |
| I-CAT Classic | CBCT | Imaging Sciences, Hatfield, Pennsylvania, USA | Zittend | 0.2–0.4 |
| I-CAT Next Generation | CBCT | Imaging Sciences, Hatfield, Pennsylvania, USA | Zittend | 0.125–0.4 |
| Illuma LFOV | CBCT | Imtec (3M), Ardmore, USA | Zittend | 0.09, 0.2, 0.3, 0.4 |
| Illuma SFOV | CBCT | Imtec (3M), Ardmore, USA | Zittend | 0.09, 0.2, 0.3, 0.4 |
| Kavo 3D Exam (powered by I-CAT) | CBCT | Gendex/Kavo Dental GmbH, Bieberach, Germany | Zittend | 0.125–0.4 |
| Kodak 9000 (C) 3D | Pano+CBCT (Ceph optie) | Kodak Dental Systems, Carestream Health, Rochester, NY, USA | Staand | 0.076 |
| Kodak 9500 LFOV | CBCT | Kodak Dental Systems, Carestream Health, Rochester, NY, USA | Staand | 0.2–0.3 |
| Kodak 9500 MFOV | CBCT | Kodak Dental Systems, Carestream Health, Rochester, NY, USA | Staand | 0.2–0.3 |
| NewTom 3G | CBCT | Quantitative Radiology, Verona, Italy | Liggend | 0.16–0.42 |
| NewTom 9000 | CBCT | Quantitative Radiology, Verona, Italy | Liggend | 0.29 |
| NewTom Vgi | CBCT (optie mobiel) | Quantitative Radiology, Verona, Italy | Staand | 0.15, 0.24, 0.3 |
| OP3000 | CBCT | Instrumentarium Dental, Tuusula, Finland | Zittend | NA |
| Orion | CBCT | Ritter Imaging, Ulm, Germany | Zittend | 0.111, 0.167 |
| PaX-500 ECT (Versa=scan type cephal) (OS Pro=One shot cephal) | Pano+CBCT (Ceph optie) | Vatech, E-WOO Technology Co, Ltd. Republic of Korea | Staand | 0.186–10 |
| Model                  | Type                        | Manufacturer                                      | Position     | Voxels                  |
|------------------------|-----------------------------|---------------------------------------------------|--------------|-------------------------|
| **PaX-Reve 3D (OS)**   | Pano+CBCT (Ceph optie)      | Vatech, E-WOO Technology Co, Ltd. Republic of Korea | Staand       | 0.08–0.25               |
| **PaX-Uni 3D (OS)**    | Pano+CBCT (Ceph optie)      | Vatech, E-WOO Technology Co, Ltd. Republic of Korea | Staand       | 0.08–0.125              |
| **Picasso Master 3D**  | CBCT                        | Vatech, E-WOO Technology Co, Ltd. Republic of Korea | Zittend/Staand | 0.2, 0.3, 0.4 (0.164)  |
| **Picasso Pro**        | CBCT                        | Vatech, E-WOO Technology Co, Ltd. Republic of Korea | Zittend      | 0.2–0.3                 |
| **Picasso Trio**       | Pano+CBCT+Ceph              | Vatech, E-WOO Technology Co, Ltd. Republic of Korea | Staand       | 0.2–0.3                 |
| **PreXion 3D**         | CBCT                        | PreXion Inc, San Mateo, USA                       | Zittend      | 0.1–0.15                |
| **Promax 3Ds**         | CBCT (Ceph optie)           | Planmeca Oy, Helsinki, Finland                    | Staand       | 0.1, 0.2                |
| **Promax3D**           | CBCT (Ceph optie)           | Planmeca Oy, Helsinki, Finland                    | Staand       | 0.16–0.32               |
| **Promax3D Max**       | CBCT                        | Planmeca Oy, Helsinki, Finland                    | Staand       | 0.1, 0.2, 0.4           |
| **PSR 9000N**          | Pano+CBCT                   | Asahi Roentgen, Kyoto, Japan                      | Zittend      | 0.1–0.15                |
| **Scanora 3D**         | CBCT                        | Soredex, Tuusulu, Finland                         | Zittend      | 0.13–0.35               |
| **Scanora 3D with Pano** | Pano+CBCT                 | Soredex, Tuusulu, Finland                         | Zittend      | 0.13–0.35               |
| **Skyview**            | CBCT                        | MyRay, Cefla Dental Group, Imola, Italy           | Liggend      | 0.16, 0.23, 0.33        |
| **Veraview3D & Epocs 3De** | Pano+CBCT (Ceph optie)     | J. Morita, Kyoto, Japan                           | Staand       | 0.125–0.2               |

**Figure 5.** Comparison of the features of CBCT produced by different manufacturers. ([http://www.sedentext.eu/content/comparison-cbct-machines](http://www.sedentext.eu/content/comparison-cbct-machines))

**Basic principles for use of CBCT in dental applications**

CBCT examinations must not be carried out unless a history and clinical examination have been performed, and they must be justified for each patient to demonstrate that the benefits outweigh the risks. CBCT examinations should potentially add new information to aid the patient’s management, and
CBCT should not be repeated routinely on a patient without a new risk/benefit assessment having been performed. When accepting referrals from other dentists for CBCT scanning, the referring dentist must supply sufficient clinical information (examination results) to allow the CBCT practitioner to perform the justification process. CBCT equipment should offer a choice of volume sizes, and examinations must use the smallest volume that provides a lower radiation dose to the patient, in accordance with the “as low as reasonably achievable” (ALARA) principle [6]. Where CBCT equipment offers a choice of resolution, it should be used compatible with adequate diagnosis and the lowest achievable radiation dose. CBCT equipment should undergo regular routine tests to ensure radiation protection, for both practice/facility users and patients. All those involved with CBCT must have received adequate theoretical and practical training for the purpose of radiation protection [10]. Dentists responsible for CBCT facilities who have not previously received “adequate theoretical and practical training” should undergo a period of additional theoretical and practical training that has been validated by an academic institution (university or equivalent); where national specialist qualifications in dentomaxillofacial radiology exist, the design and delivery of CBCT training programs should involve a dentomaxillofacial radiologist. For dentoalveolar CBCT images of the teeth, their supporting structures, the mandible, and the maxilla up to the floor of the nose, for example, 8 cm X 8 cm or smaller FOVs should be scanning. Larger FOVs (for example, temporal bone) and all craniofacial CBCT images (FOVs extending beyond the teeth, their supporting structures, the mandible [including the TMJ], and the maxilla up to the floor of the nose), the clinical evaluation (radiological report) should only be done when necessary [4,6,10] (Figure 6).

![Different dental tomography equipment in horizontal and vertical positions](image)

Figure 6. Different dental tomography equipment in horizontal and vertical positions

Effective radiation dose comparisons in µSv with CBCT systems differ according to the aim of the examination [11-13] (Figure 7). The main screen for the CBCT shows panoramic, antero posterior, lateral, and horizontal section in images and gives information about the number of scanned images, voxel size, patient name, date of birth, and date of the scan. There are different special CBCT screens for CBCT software; Implant Planning Screen is one of them. It allows physicians to plan and design the implant length and diameter in a suitable place over the jaws. Physicians can measure the bucco-lingual and vertical distance (Figure 8). This screen is useful for comparing different patient groups.
### Effective Radiation Dose Comparisons in µSv with CBCT Systems

| Examination                                | Effective Dose (µSv) |
|--------------------------------------------|----------------------|
| Intraoral radiograph (per exposure)        | < 8.3                |
| Dental panoramic radiograph                | 9-26                 |
| Dental cephalometric radiograph            | 3-6                  |
| Cone beam CT (dento-alveolar) (focus field of view) | 5 to 38.3*          |
| Full-mouth series                          | 35 to 388            |
| Cone beam CT (craniofacial)                | 68 to 599            |
| Medical fan beam CT scan (maxilla and mandible) | 2,000               |

Source:
- White, Stuart C. Oral Radiology: Principles and Interpretation, 6th Edition. Mosby, 2008.
- Ludlow, John B. Technical Paper: Dosimetry of Kodak 9000 3D, June 19, 2008.

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**Figure 7 A, B, C.** Effective radiation dose comparisons in µSv with CBCT systems
Matrix Multiplanar Reconstruction (MPR) Screen of Special CBCT Screen software, the images obtained of the skull can be examined and scanned in three planes (coronal, sagittal, and axial planes) and private custom planes by physicians to detect pathologies (Figure 9).

In the temporomandibular joint screen of Special CBCT Screens, physicians can inspect the temporomandibular joint in 3D from different sides. Different sections of the joint can also be inspected in three planes (Figure 10).
The Cephalometrics Examination Screen of Special CBCT Screens is useful for orthodontic diagnosis and treatment planning. This screen can be used to detect upper airway obstructions (Figure 11).

There are different useful accessory options in the CBCT software. The Hounsfield unit (HU) scale is one of them. The HU scale is a numerical scale that can define the density of the images in x-rays and CBCT in particular. It was developed by Godfrey Newbold Hounsfield in 1972. We can conduct a quantitative assessment of the density of bone and mineralized tissues using the HU scale in different patient groups. In a CBCT scan, the HU is proportional to the degree of x-ray attenuation by the tissue. In CBCT, the degree of x-ray attenuation is shown in gray scale [13-16]. According to the HU scale, we can define the condition of tissues, especially bone destruction. Each voxel has an HU unit between -1000 and +3000 [17] (Figures 12, 13).

Figure 10. Temporomandibular joint screen

Figure 11. Cephalometrics Examination Screen
Figure 12. Mean of the HU scale

Hounsfield Unit (HU) scale

- Each voxel has a unit between -1000 / +3000
  - Air: -1000
  - Oil: -50
  - Water: 0
  - Soft tissue like muscle: +40
  - Tartar: +100 ile +400
  - Bone: +1000
  - Enamel: +3000
The CBCT is used in pediatric dentistry to examine the root resorption stage of the primary teeth; it is 3D and measures in real distance units [16] (Figure 13). We can see the entire skull in different aspects with CBCT data, such as the skull with skin, with the muscle (shown in shadows), and just the bone. CBCT can be used to examine the root resorption stage of the primary teeth in 3D and measure them in volumetric units using Mimics or a 3D slicer. The following are the most common and commercially available medical image processing software programs used for medical image processing and the design and development of medical applications based on CT/MRI and scanned data (dicom data): Mimics® Innovation Suite: Mimics, 3-matic (Materialise NV: www.materialise.com), ScanIP (Simpleware: www.simpleware.com), and Geomagic Wrap, Design X & Freeform (Geomagic: www.geomagic.com), 3D slicer, Dolphin, SimPlant, Implant 3D. Any part of the skull following segmentation with either Mimics or a 3D slicer can be seen in 3D and measure the volume of a sample (Figure 14). The root intercourse of the primary teeth roots with permanent crowns can be examined in 3D, and any part of the teeth can be measure in volumetric units using Mimics [7,18,19]. These accessory programs give physicians an easy way to do the aimed examination (Figure 14).

**Figure 13.** (A) Measurement of bone destruction using the HU scale and 3D screen; (B) Clinical uses of CBCT in pediatric dentistry to examine the root resorption stage and measure the root length

**Figure 14.** CBCT can be used to examine the root development level of permanent teeth, the root resorption stage of the primary teeth in 3D as well as to measure in volumetric units
CBCT can be used to examine any part of the teeth, such as the root development level, enamel, dentine, and pulp in 3D, measurement can be in volumetric unit and also for surface measurement [18] (Figure 15–18).

Figure 15. CBCT can be use to calculate the volume and surface measurement of the enamel, dentine, and pulp tissue

Figure 16. CBCT can be used to examine the shape of the root canals in three planes

MicroCT can be used for a more accurate examination of any part of the teeth and calculate the volume and surface measurement of the enamel, dentine, and pulp tissue. But Micro CT generally should not be used in human beings due to its high radiation doses, and it is only suitable for small samples and in vitro studies [20] (Figure 19).
Figure 17. CBCT is more successful in the determination of root fractures and the angles of fracture lines in three planes and volumetric units

Figure 18. CBCT is more successful for the evaluation of the periapical lesion and bone destruction with HU scale and 3D view in volumetric units
Figure 19. CBCT can be used to measure all the parts of a root fracture as well as the space between the parts in volumetric units and surface measurement with Mimics, 3D slicers, and others.
Figure 20 A, B, C. Examination of any part of the teeth and calculation of the volume and surface measurement of the enamel, dentine, and pulp tissue using MicroCT.

CBCT can be used to examine anomalies, such as dilacerations (Figure 20, 21). Images obtained from CBCT at different angles can be used to determine the accurate location of a supernumerary tooth, impact tooth, and odontoma [22,23] (Figures 22, 23).
Figure 21. Different views of the dilaceration case with CBCT images

Figure 22. The central incisor’s location can be accurately determined from images portraying different sides; in this case, the tooth is at the base of the nose

Figure 23. Odontoma and mesiodens tooth
The 3D CBCT Dicom data can be analyzed with Mimics software to print any part of the body in 3D for inspection and search pathologies. Dicom data can use any part of the skull for segmentation, after the segmentation data could be used with a 3D printer. This utility option allows physicians to prepare and design patient-specific customized implants for any part of the body [24] (Figure 24).
Figure 24 A, B, C, D. Dicom data of the 3D CBCT segmentation can be done. It could be used to obtain 3D volumetric models with 3D print (https://3dprintingindustry.com/news/move-over-titanium-3d-printed-bone-implants-are-here-49262/), http://www.abc.net.au/news/2015-06-20/melbourne-man-receives-titanium-3d-printed-prosthetic-jaw/6536788)

Advantages of CBCT

- All the images obtained from a patient can be sent to the patient’s physician digitally and can be archived in any computer.
- Physicians are able to examine images in different three planes and in the area they want.
- Dicom data of 3D CBCT could be used with other software for planning for an implant, orthodontic treatment, diagnosis pathologies, and the inspection of any part of the body.
- The radiation doses are lower than in medical tomography.
- In cases of necessity, limited areas of the skull can be selected for examination, thus limiting the parts of the skull exposed to radiation.
- A single scan produces a wide variety of views and angles that can be manipulated for complete evaluation. For dental applications with 0.3 voxels in 8.9 seconds, 440 images can be obtained in three plans, and with 0.125 voxel in 26.9 seconds, 624 images can be obtained.
- The obtained images are shown in their real size; growth (magnification) and distortion do not occur.
- The images’ real dimensions can be measured with approximately 0.1 precision. Accurate data lead to better treatment planning decisions and potentially more predictable outcomes.
- Density measurements can be performed on images to measure bone destruction and other hard tissues.
- The images can be analyzed in 3D; volumetric measurement and surface measurement can also be done.
- The focused x-ray beam reduces scatter radiation, resulting in better image quality.
- 3D CBCT scans provide more information than conventional dental x-rays, allowing for more precise treatment planning.
- Sample models for educational purposes can be acquired by using the computer software.

Disadvantages of CBCT

- CBCT devices are expensive.
- Dentists should undergo a period of additional theoretical and practical training on CBCT to examine the image data on the computer.
- A fast computer is required to examine the images.
- More time is required to examine the images.
- The radiation dose is higher than in conventional dental radiography. There is a slight risk of cancer being caused by excessive exposure to radiation. However, the benefit of an accurate diagnosis far outweighs the risk.
Periodic adjustment is necessary to obtain quality images. Monthly and annual calibrations are necessary to protect and increase the image quality of CBCT devices.

The extreme rise and fall in the temperatures of the area surrounding the device can damage the quality of the images.

Because children are more sensitive to radiation, they should have a 3D CBCT exam only if it is essential for making a diagnosis and should not have repeated CBCT exams.

2. Conclusion
The European Radiation Protection Commission Guidelines stated that all CBCT examinations must be justified on an individual basis by demonstrating that the potential benefits to the patients outweigh the potential risks. CBCT examinations should potentially add new information to aid the patients’ management. A record of the justification process must be maintained for each patient [25]. CBCT is a useful device with a specific imaging modality and an important technology in comprehensive dental evaluation; it is one of the most important dental diagnostic innovations that has been developed last decades. Based on the literature, the CBCT applications in dental practice relate to all specialties of dentistry. However, CBCT scans must not be performed unless they are necessary, and the benefits should clearly outweigh the risks. Future enhancements will most likely be directed toward reducing scan times and radiation doses. CBCT is capable of providing accurate, submillimeter-resolution images, with data allowing 3D visualization of the maxillofacial region. Each day, more computer softwares are produced for use with CBCT and can be used as product visualization tools providing educative models. The following are the most common and commercially available medical image processing software that are used for medical image processing and the design and development of medical applications based on CT/MRI and scanned data (dicom data) with CBCT: Mimics, 3-matic, ScanIP, Geomagic Wrap, Design X & Freeform, 3Dslicer, Dolphin, SimPlant, and Implant 3D. Any part of skull after the segmentation with computer software programs can be seen in 3D and measure the surface and volume of samples. The root intercourse of a primary tooth root with a permanent crown can be examined in 3D, and any part of the tooth can be measure in volumetric unit Mimics. Moreover, any part of maxilla facial hard tissues can be calculated in HU scales for research. In addition, MicroCT can be use in in vitro studies to more accurately examine any part of the teeth and calculate the volume and surface measurement of the enamel, dentine, and pulp tissue. These futuristic accessory programs give physicians an easy way to accomplish more, and to develop over time.

References
[1] Scarfe W C, Levin M D, Gane D and Farman A G 2009 Use of cone beam computed tomographyin endodontics. Int. J. Dent. 2009 1-20. doi:10.1155/2009/634567.
[2] Görgen V A, Güler Ç and Kızılcı E 2014 Diş Hekimliğinde Konik Işılı Bilgisayarlı Tomografi (CBCT) Cone Beam Computed Tomography In Dentistry (Cbt). İnönü Üniversitesi Sağlık Bilimleri Dergisi 3 36-40.
[3] Radiologyinfo.org. for patients. Dental Cone Beam CT. https://www.radiologyinfo.org/en/info.cfm?pg=dentalconect.
[4] Alamri H M, Sadrameli M, Alshalhoob M A, Sadrameli M and Alshehri M A 2012 Applications of CBCT in dental practice: A review of the literature. Gen Dent. 60 390-400.
[5] Orhan K 2012 Diş Hekimliğinde Konik Işılı Komputerize Tomografinin (KIKT) Yeri ve Önemi 2012 Yeditepe Üniversitesi Diş Hekimliği Fakültesi Dergisi. 3 6-17.
[6] Scarfe W C and Farman A G 2008 What is Cone-Beam CT and How Does it Work? Dent. Clin. North. Am. 52 707–30.
[7] Tumen E C, Yavuz I, Tumen D S, Hamamci N, Berber G, Atakul F and Uysal E 2010 The detailed evaluation of supernumerary teeth with the aid of cone beam computed tomography Biotechnol. Biotechnol. Eq. 24 1886-1892.
[8] Dogan M S and Yavuz I 2016Using conic-beam computer tomography in diagnosing post-trauma root fractures in children. J. Pediatr. Neonatal Care. 4 1-3.
[9] Doğan M S, Callea M, Yavuz I, Aksoy O, Clarich G, Günay A, Günay A, Güven S, Maglione M, Akkuş Z 2015 An evaluation of clinical, radiological and three-dimensional dental tomography findings in ectodermal dysplasia cases Med. Oral Patol. Oral Cir. Bucal. 20 340-6.

[10] Basic Principles for Use of Dental Cone Beam CT Consensus. Guidelines of the European Academy of Dental and Maxillofacial Radiology. January 2009 (http://eadmfr.eu/sites/default/files/downloads/Basic_Principles_for_Use_of_Dental_Cone Beam_CT.pdf).

[11] Cone Beam Computed Tomography: How safe is CBCT for your patients? http://www.dentaleconomics.com/articles/print/volume-101/issue-1/features/cone-beam-computed-tomography-how-safe-is-cbct-for-your-patients.html.

[12] Radiation doses and risks of CBCT. http://www.sedentexct.eu/content/radiation-doses-and-risks-cbct.

[13] Sean K. Carlson. Understanding CBCT dosimetry. http://www.i-cat.com/assets/documents/Articles--Reviews/OPCarlson072012.pdf.

[14] Razi T, Niknami M and Ghazani F A 2014 Relationship between hounsfield unit in CT scan and gray scale in CBCT. J. Dent. Res. Dent. Clin. Dent. Prospects. 8 107–110.

[15] Mah P, Reeves T E and Mc David W D 2010 Deriving hounsfield units using grey levels in cone beam computed tomography. Dentomaxillofac. Radiol. 39 323–35.

[16] Kaya S, Adiguzel O, Yavuz I, Tumen E C and Akkus Z 2011 Cone-beam dental computerize tomography for evaluating changes of aging in the dimensions central superior incisor root canals Med. Oral Patol. Oral. Cir. Bucal. 16 463-6.

[17] Lamba R, Mc Gahan J P, Corwin M T, Li C-S, Tran T, Seibert J A and Boone J M 2014 CT hounsfield numbers of soft tissues on unenhanced abdominal CT scans: variability between two different manufacturers’ MDCT scanners. AJR Am. J. Roentgenol. 203 1013–20.

[18] Adisen M-Z, Yilmaz S, Misirlioglu M and Atil F 2015 Evaluation of volumetric measurements on CBCT images using stafne bone cavities as an example. Med. Oral Patol. Oral Cir. Bucal. 20 580-6.

[19] Le C H, Pham B M, Tran D T, Lam K, Le T H, Vo D L, Mengisu S, Packianather M S 2016 An integrated system and framework for development of medical applications and products based on medical imaging data. IFMBE Proc. 20 260-3.

[20] Swain M V and Xue J 2009 State of the art of micro-CT applications in dental research. Int. J. Oral Sci. 1 177–88.

[21] Durack C and Patel S 2011 The use of cone beam computed tomography in the management of dens invaginatus affecting a strategic tooth in a patient affected by hypodontia: a case report. Int. Endod. J. 44 474–83.

[22] Marques-da-Silva B, Baratto-Filho F, Abubara A, Moura P, Losso E M and Moro A 2010 Multiple taurodontism: the challenge of endodontic treatment. J. Oral Sci. 52 653-8.

[23] Patel S 2010 The use of cone beam computed tomography in the conservative management of dens invaginatus: a case report. Int. Endod. J. 43 707–13.

[24] Swart P, Wicklein M, Sykes D, Ahmed F and Krapp H G 2016 A quantitative comparison of micro-CT preparations in dipteran flies. Sci. Reports. 6 39380. DOI: 10.1038/srep39380.

[25] European Commission 2014 Guidelines on Radiation Protection Education and Training of Medical Professionals in the European Union. 2014. http://ec.europa.eu/energy/sites/ener/files/documents/175.pdf.