Cone Beam Computed Tomography

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Cone Beam Computed Tomography

- Some of the common types:

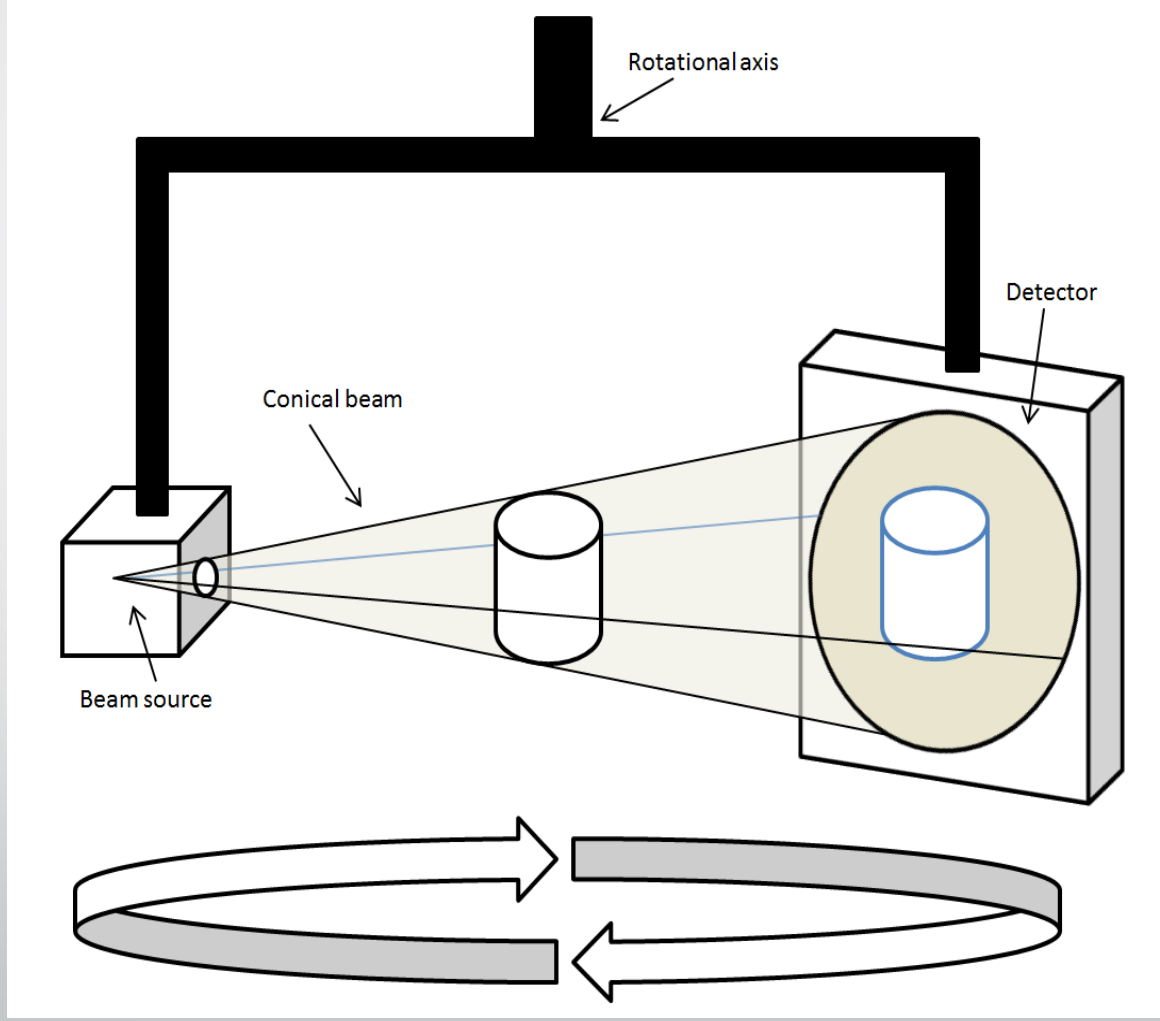
What's In A Name

- Cone beam computed tomography (CBCT)
- C-arm CT
- Cone beam volume CT
- Flat panel CT

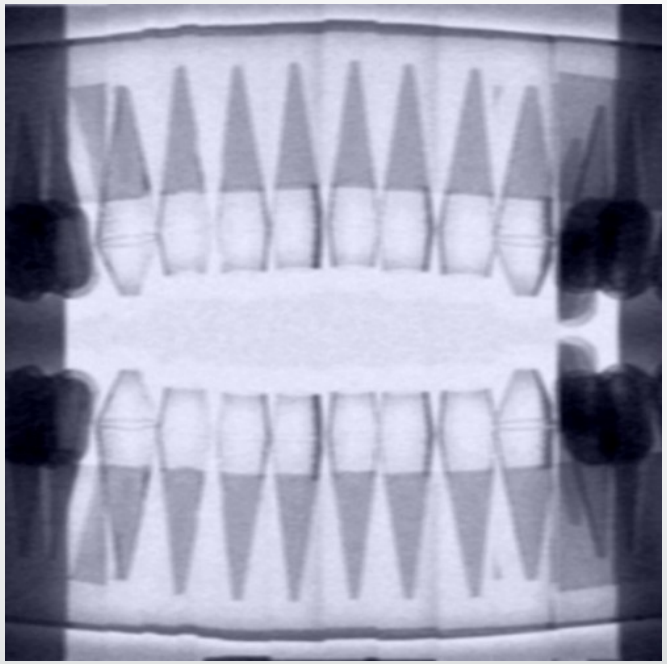
What Is It?

- CBCT is a medical imaging technique that consisting of x-ray computed tomography where the x-ray beam is divergent, forming a cone

Cone Beam X-ray Production



Phantom



Which Specialties Use This Modality

- CBCT is used for diagnosis and treatment planning in many specialties:
  - Implant Dentistry
  - ENT
  - Orthopedics
  - Interventional Radiology
  - Integrated CBCT is important for patient positioning and verification in image-guided radiation therapy
  - Dentistry
    - Oral surgery
    - Endodontics
    - Orthodontics
    - General dentistry

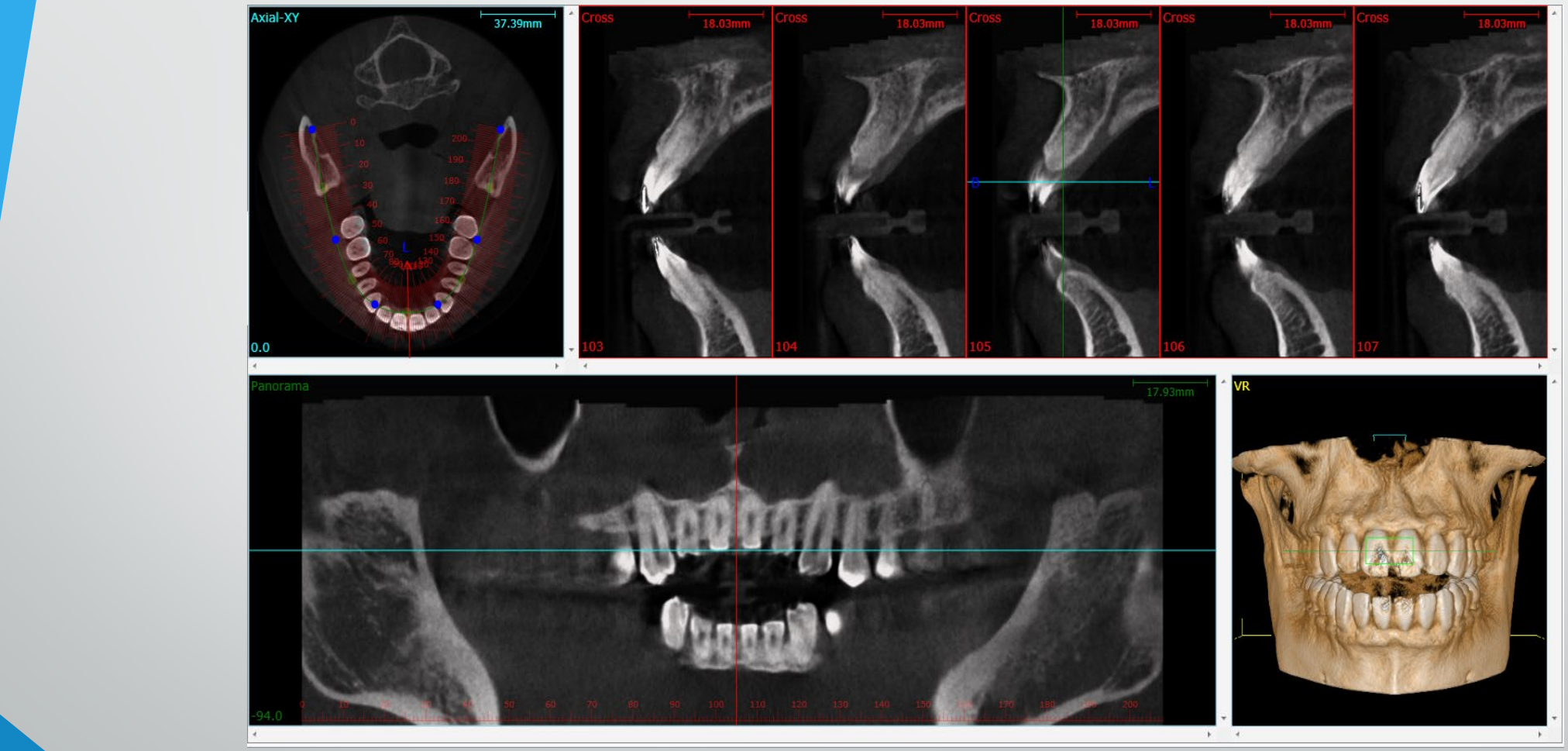
Imaging

- A single 200-degree rotation around the head
- Creates about 600 images
- Acquires a volumetric data set
- Produces a digital volume that is composed of 3 dimensional voxels
  - This digital volume can be manipulated and visualized with specialized software

Similar to Traditional CT (MDCT)

- Traditional CT is acquired in a fan beam configuration or spiral acquisition
  - Differs during reconstruction and energy or output parameters

Slices

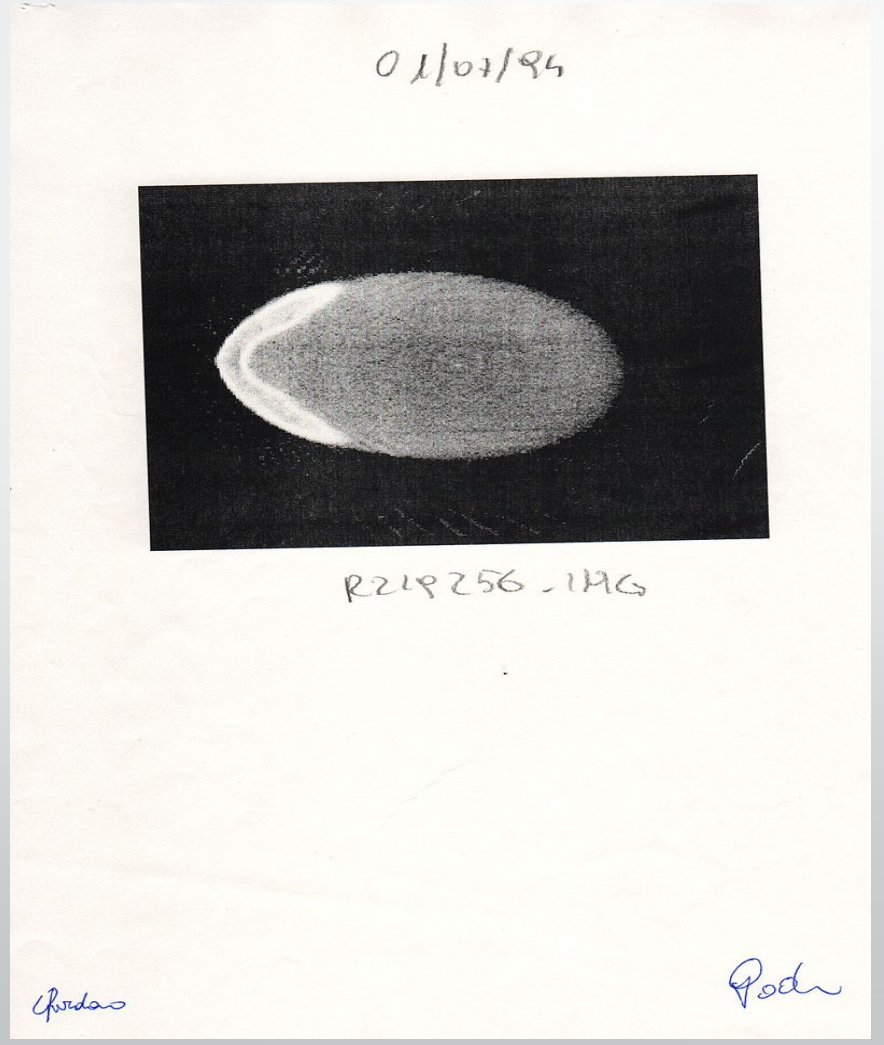

Axial-XY
37.39mm
0.0
Cross
18.03mm
103
104
105
106
107
Panorama
17.93mm
-94.0
VR

History

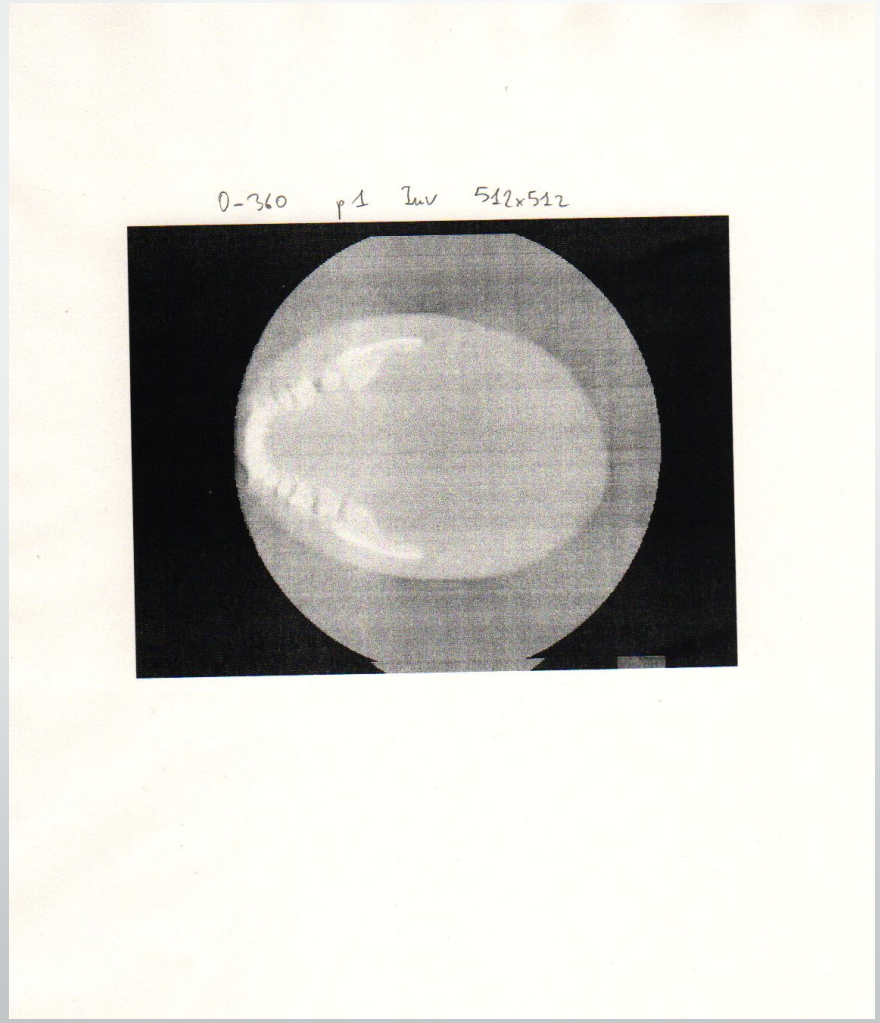
- First introduced in Europe in 1996
- Crossed the ocean to the US in 2001
- The research team received an award in 2013 for the invention of CBCT

Festival della Scienza in Genova, Italy

Axial Image from the 1st CBCT- July 1,1994



Axial Image from the 1st CBCT- July 1,1994



Notes

PRIMA ACQUISIZIONE TOTALE

Memorizzata in d.r.: PRIMAACQ

Caratteristiche: Tubo Tipo = 60kV 10mA RT { FASE CICLI: 20 3msec; BASE CICLI: 0 0msec
Dist Sorg Det = 847 mm
Dist Sorg CR = 712 mm
Meccanica = PERNO GIREVOLE CON PERNO STORTO
Griglia = NO
Num Img x Step = 1
Pr UI detector = 64 ÷ 455
Guadagno = 40
Offset = 29
Soglia Int = 0
Soglia Sup = 255
Num Step = 350

Immagini: SE NON SEGNATO DIVERSAMENTE X IL BLANK VEDI IMG.BLK (8/6/94)
E PER LA TARATURA GEO VEDI TARAT.GRL (8/6/94)

RPF1307.IMG => RPF di 15 piani (step tra piani 4) ottenuta con alg 1 e blank normale. Matrice 512x480, con 350 viste - Con prefiltro STOOTHING fatto nella IP8.
Comprende "sbiascola" + mezzo denti inferiori.
Contiene file RPF2.DAT.

Multiple Areas of Applications

- Implantology
- Orthodontics
- Orthopedics
- Image-guided radiation therapy
- Interventional radiology

For this presentation we will limit discussion to Dentistry

Implantology

- Offers useful information for the assessment and planning of surgical implants

Orthodontics

- 3D reconstruction offers an undistorted view of the dentition than can accurately visualize both erupted and non-erupted teeth, tooth root orientation and anomalous structures that 2D radiographs cannot

Amazing Images

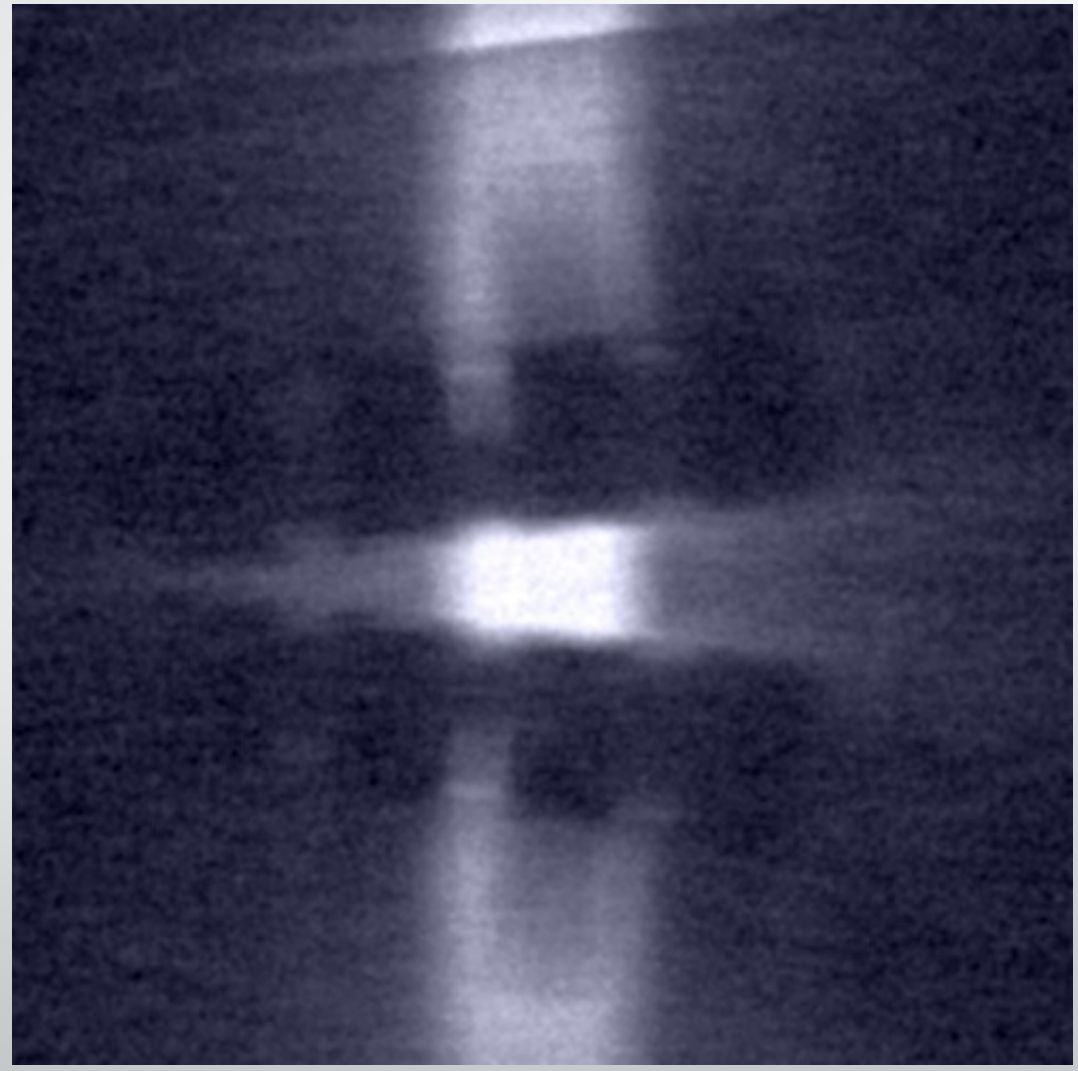
Technical Limitations

- Image quality
- Time
  - Set up
  - Length of acquisition
  - Image reconstruction

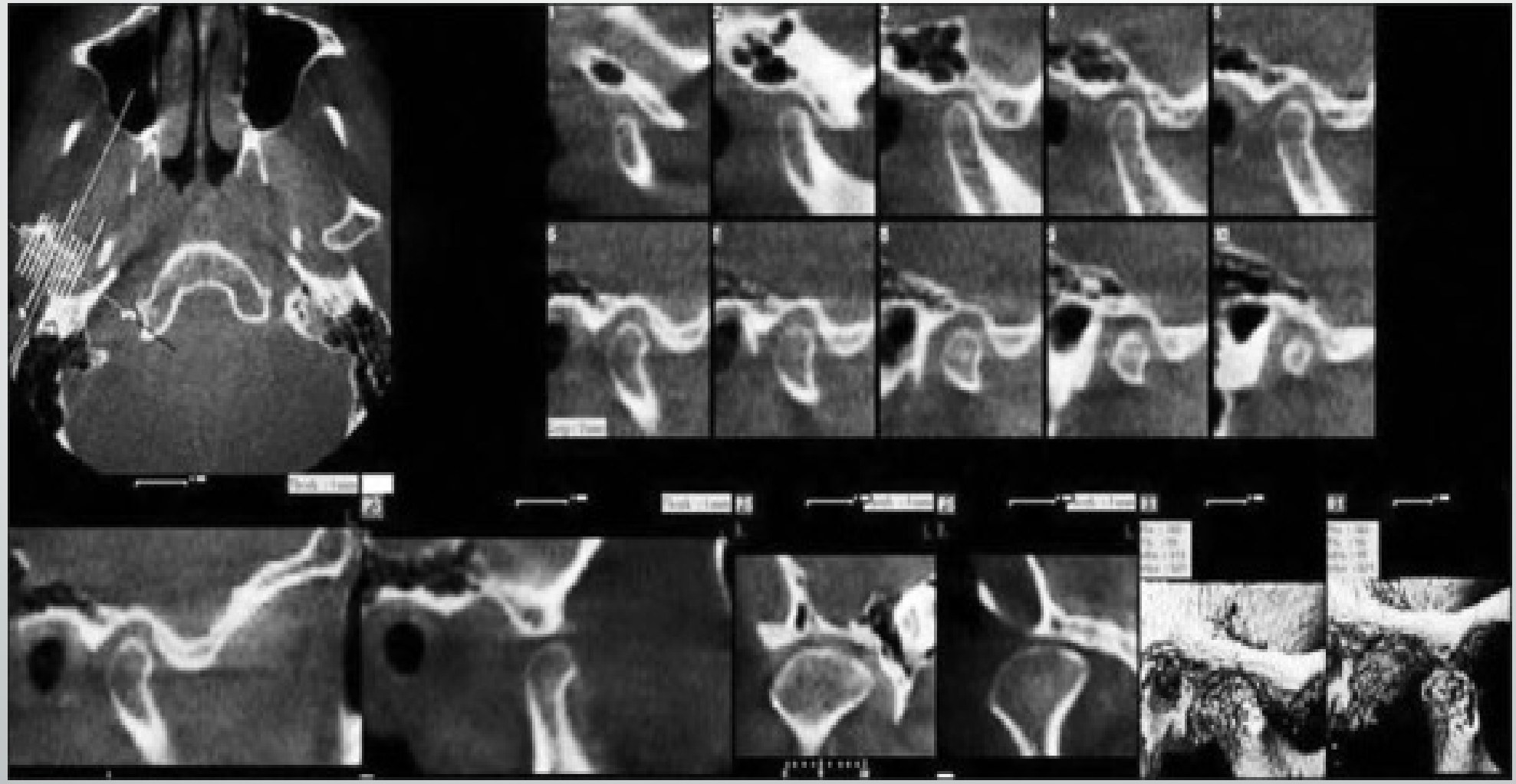
Image Quality

- Wider collimation in CBCT leads to increased scatter radiation
- This degrades the image quality
  - Artifacts
  - Decreased contrast-to-noise or signal-to-noise
  - Temporal resolution of cesium iodide detectors in CBCT slows the acquisition time to approximately 5 to 20 seconds
  - This increases motion artifacts

Noise Degraded Image



Fantastic Detail



Time

- Reconstruction for CBCT is about 1 minute
  - This is due to complex cone beam reconstruction algorithms
- Reconstruction for MDCT is real time

Reconstruction Algorithms

- Similar to MDCT
  - Filtered backprojection
  - Iterative reconstruction
  - May also use FDK algorithm in addition to or in place of the above

Risks

- Radiation doses from dental CBCT are about 96% lower than MDCT
- Length of exposure time is much less than conventional CT
- Much higher exposure than standard 2D dental x-ray.

Standard of Care

- Use
  - the smallest field of view
  - smallest voxel size
  - Lowest mA setting
  - Shortest exposure time
  - Pulsed exposure mode of acquisition

Disadvantages

- Increased problems with motion artifacts (1st generation equipment)
- Lack of appropriate bone density determination

Hounsfield Scale

- The Hounsfield scale is used to measure radiodensity
- In MDCT scans it provides an accurate absolute density for the type of tissue depicted. Also know as the CT number
- In CBCT it is an inaccurate measurement because different areas of the scan appear with different greyscale values.
  - This is dependent on the relative positions in the organ being scanned
  - They can have identical densities but the image value of a voxel of an organ depends on the position in the image volume

Comparing MDCT to CBCT

- HU measured in the same anatomical area will not be identical
- This makes them unreliable for determining site-specific, radiographical identified bone density for the potential placement of dental implants
  - So far there is no reliable data to relate the CBCT HU values to bone quality

No Standardized System

- Currently there isn't a standardized system for scaling the grey levels that represent the reconstructed density values.
  - This makes it unreliable to compare values from different machines
  - When there are further advancements in reconstruction algorithms allowing for improved area detectors and enhanced postprocessing the problem will be reduced or solved
  - Research is on-going but not enough in the literature regarding results

New Paradigm in the Works

- Some in the dental community feel it is time for a shift-
  - They want to go from the ALARA concept to the ALADA concept
    - ALARA=As Low As Reasonably Achievable
    - ALADA=As Low As Diagnostically Acceptable

Dose in CBCT

- The dose delivered by CBCT is dependent on several factors
  - Size of the field of view (FOV)
  - Exposure time (s)
  - Tube current (mA)
  - The energy/potential (kV)

  It is vital the potential benefits outweigh the risks of the exposure

  Clinicians need training in ordering and interpreting-

  Staff needs training to operate the equipment properly

Technology has Outpaced Regulations

- The idea for cone beam CT was conceived in 1982
- Development was delayed to allow computer technology to advance
- 2005 4 different companies had scanners available
- 2008 16 companies were producing 23 different scanners
  - All can deliver sub-mm spatial resolution. This gives high contrast sinus structure visualization, sub-mm at air-bone interfaces, middle and inner ear components and fine dental structures
    - In 2017 there were approximately 5,500 in the US.
    - 300,000 pediatric studies
    - 3,876,00 adult studies

Who is Using this Technology?

- In 2017 there were approximately 5,500 in the US.
  - 300,000 pediatric studies
  - 3,876,00 adult studies
  - Practice distribution is even between general practice and oral surgery

Abbreviations

- AAPM - American Associatin of Physicists in Medicine
- ADA - American Dental Association
- ALARA - As Low As Reasonably Achievable
- CBCT - Cone Beam Computed Tomography
- CDRH - Center of Devices and Radiological Health
- CTDI - Computed Tomography Dose Index
- FOV - Field of View
- IAC - Intersocietal Accreditation Commission
- ICRP - International Council on Radiation Protection

Abbreviations Continue

- QE - Qualified Expert
- QMP - Qualified Medical Physicist
- MDCT - Multi-detector Computed Tomography
- NCRP - National Council on Radiation Protection and Measurements
- NEXT - Nationwide Evaluation of X-ray Trends
- QA - Quality Assurance
- QC - Quality Control
- RT - Registered Technologist
- USEPA - U.S. Environment Protection Agency
- USFDA - U.S. Food and Drug Administration

Glossary

- CBCT
- A CBCT machine is one the utilizes a divergent x-ray beam with a conical or pyramidal shape.
- It uses a flat panel detector
- Can generate 3D images
- Currently there are 2 categories of CBCT machines
  - Machines that generate 20 mA and 100 kV or less
  - Machines that generate greater than 20 mA and 100 kV
    - Training for operators differ with the output of the equipment

Quality Assurance

- Quality assurance is the process through which the quality management system gives confidence that the current standards and/or requirements are met.

Quality Control

- Quality control is the process where the actual quality performance is measured
- These measurements are compared to existing standards
- Corrective actions may be necessary to maintain or regain conformance with the existing standards

Qualified Medical Physicist

Qualified Medical Physicist who meets each of the following standards:

- Has earned a master's or doctoral degree in physics, medical physics, biophysics, radiologic physics, medical health physics or equivalent disciplines from an accredited college or university and;
- Has been granted certification in the specific subfield(s) of medical physics and its associated medical health physics aspects by an appropriate national certifying body and abides by the certifying body's requirements for continuing education

Quality Expert

- Qualified Expert
  - An individual who is granted professional privileges based on education and experience to provide clinical services in diagnostic medical physics by the Agency

Patient Dose Comparisons

Cone-Beam CT Scanner	Effective Dose in μSv[A]	Digital Panoramic Equivalent [B]	Number of Days of Annual Per Capita Background Radiation[C]
Sirona Orthophos XG 3D	32–85 depending on setting*[1]	2.2–6	4–10.3
Galileos Comfort	70–128 depending on setting*	5–9.1	8.5–15.6
I-CAT Next Generation	45–83 depending on FOV/settings**	3.2–5.9	5.5–10.1
NewTom 3G	68*	4.9	8.3
Kodak CS 9300	18–200 depending on the FOV/settings*[2]	1.3–14.3	2.2–24.4
Comparison with Somatom Sensation 32-row/64-slice MultiDetector CT	860*	61.4	104.9

Image Gently/Image Wisely

Recommendations From AAE and AOMR Joint Position Statement

- The position statement was published in an update 2015/2016
  - There are 7 recommendations listed in the publication
  - They state when this group advise use of CBCT or other imaging modalities in the treatment planning

Their conclusion “CBCT is an emerging technology that is revolutionizing the approach to endodontic care of dental patients. The guidance in this statement is not intended to substitute for a clinician’s independent judgment in patient care. The use of limited FOV CBCT should be considered on a case-to-case basis, with due consideration given to the risks and benefits of exposing the patient to ionizing radiation, the patient’s history, clinical findings and pre-existing radiographs so that superior treatment can be provided to the general public in need of endodontic care.”

The full document can be found searching “AAE and AAOMR Joint Position Statement-Use of Cone Beam Computed Tomography in Endodontics-2015/2016 Update

References

- Shekhar Bhatia and Shivani Kohli. Cone-beam computed tomography usage: An alert to the field of dentistry; Imaging Science in Dentistry, 20196 June, 46(2): 145-146
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- American Association of Endodontists: Cone Beam Computed Tomography
- Wikipedia: Cone beam computed tomography
- Technical White Paper: Cone Beam Computed Tomography For Dental Applications, November 2017 pages 12-38
- Minnesota Department of Health, X-ray Rule-4732

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