牙科放射線診斷的演進
低輻射劑量的牙科 3D 診斷工具

中華民國口腔顎顏面放射線學會

中華牙醫學會第十七屆第一次會員大會
暨第三十二次學術研討會

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Clinical Application of Cone Beam Computerized Tomography (CBCT) in Dentistry

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Introduction

We work on a 3-D patient:

- *we diagnose 3-D pathology*
- *we place 3-D dental implants*
- *we provide 3-D restorations and prostheses*
- *we apply 3-D forces*

Shouldn't we diagnosis and treatment plan using 3-D imagery?

Current Radiographic Shortcomings

- Standard dental films (PA's, BW'S) suffer from the same inherent limitations of all planar 2D projections - magnification, distortion, superimposition and misrepresentation of structures.
- Panoramic - ~25% magnification (Horizontal), 2D

Benefits of 3D Imagery

PA X-ray of a asymptomatic incisor fails to reveal the true nature of the extensive lesion compared to a CBCT

Dawood et al. British Dental Journal 2009; 207: 23–28

Outline of Presentation

- Cone Beam Volumetric Image (CBVI)
  = Cone Beam Computed Tomography (CBCT)
- The history of the CBCT
- What is a CBCT and how does it work?
- Why are we using this radiographic image?
- When should we prescribe one?
- Clinical application of CBCT in dental practice
- Future predictions for CBCT imaging
- Clinical case practice

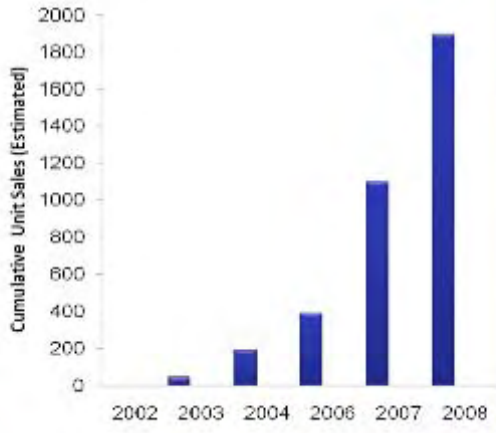
CBCT History

- First developed for use in angiography
- Mozzo et al. (1998) and Arai et al. (1999) reported the first CBCT unit developed specifically for dental use (NewTom 9000 and 3DX Accuitomo)
- Other similar devices introduced around that time included the 3D X micro-CT in 2000.

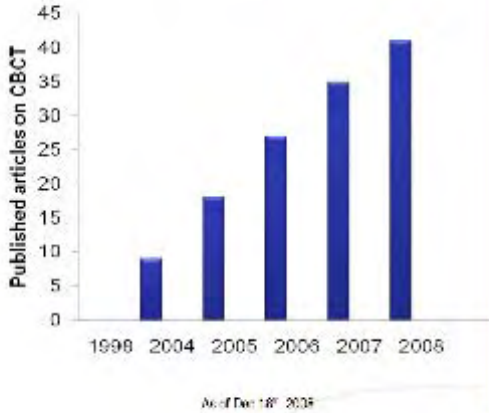
Mozzo P, Procacci C, Tacconi A, Martini PT, Andreis IA. A new volu- metric CT machine for dental imaging based on the cone-beam technique: pre- liminary results. Eur Radiol 1998: 8: 1558–1564.
Arai Y, Tammisalo E, Iwai K, Hashi- moto K, Shinoda K. Development of a compact computed tomographic apparatus for dental use. Dentomaxillofac Radiol 1999: 28: 245–248.

CBCT – Adoption

- Introduced to the US in 2000
  - 2002 (~10)
  - 2003 (~30)
  - 2004 (~75)
  - 2005 (~175)
  - 2006 (~350)
  - 2007 (~1100)
  - 2008 (~2000)
  - 2009 (??)
- Rapid adoption in dentistry by
  - Dental Schools
  - Dentists, Specialists and Imaging Centers



CBCT – Publications in the OMF region



Current Available CBCT Scanners

The major difference is in the detector used.

A, NewTom 3G (courtesy of Aperio Services, Sarasota, FL). B, i-Cat (courtesy of Imaging Sciences, Hatfield, PA). C, ILUMA (courtesy of IMTEC Corp, Ardmore, OK). D, ProMax 3D (courtesy of Planmeca Oy, Helsinski, Finland). E, CB MercuRay (courtesy of Hitachi Medical System America Inc, Twinsburg, OH). F, Dental CBCT (courtesy of TeraRecon Inc, San Mateo, CA). G, 3D Accuitomo (courtesy of J Morita USA, Irvine, CA). H, Sirona Galileos (courtesy of Sirona Dental Systems North America, Charlotte, NC).
Quereshy, Savell, and Palomo. Cone Beam Computed Tomography. J Oral Maxillofac Surg 2008.

CBCT Image Acquisition

1) X-ray generation
2) Image detection
3) Image re-construction
4) Image display

Components of CBCT Image Production

Acquisition and Image Detection

Image Reconstruction

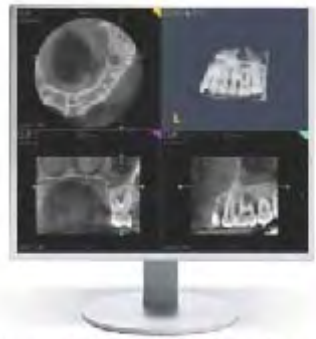
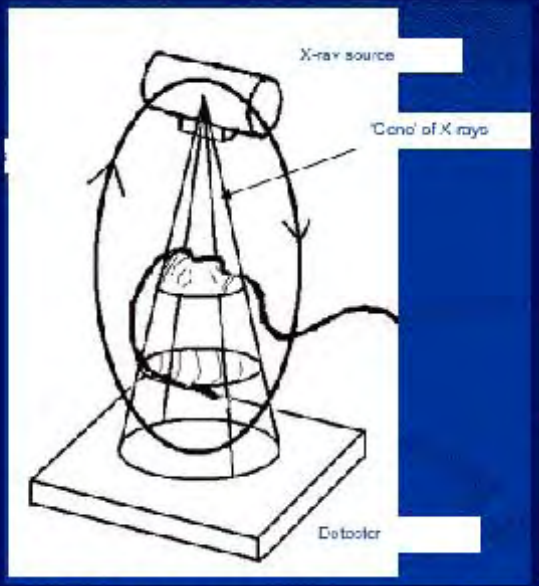
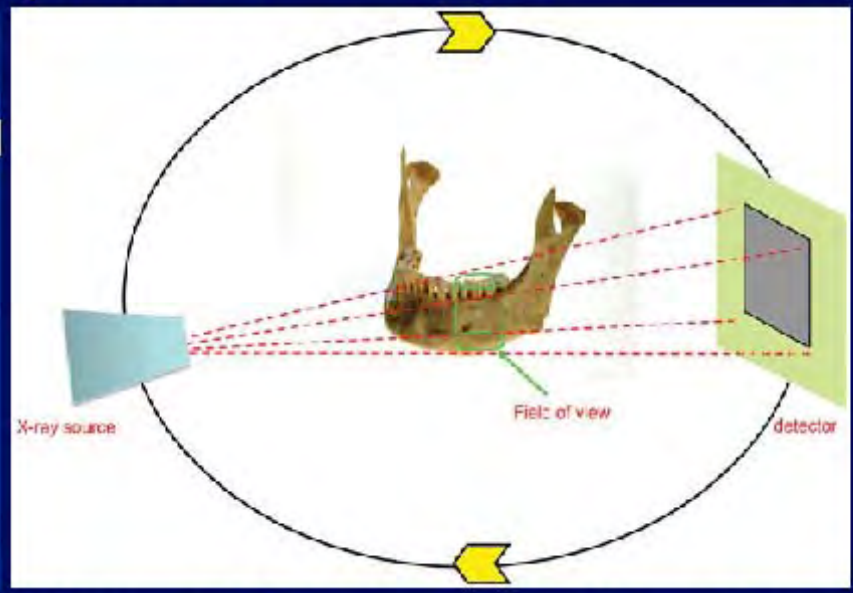


Image Display / Visualization

Principles of CBCT

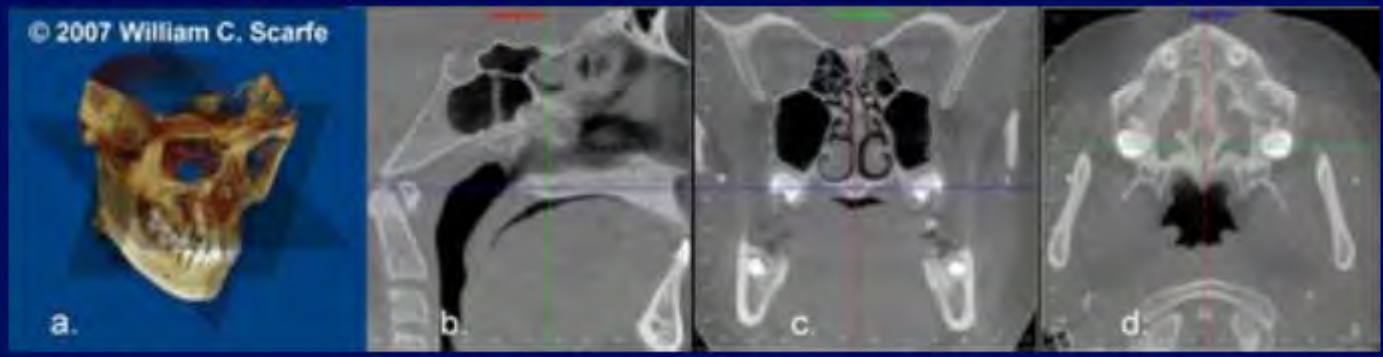




- CBCT uses a rotation in which a pyramidal or cone - shaped x-ray beam is directed towards an area x-ray detector
- Multiple 2D projection images are acquired for a field of view (FOV) selected according to the region of interest (ROI)
- Reconstruction algorithms are used to convert them into a three-dimensional data set. Scarfe et al. J Can Dent Assoc 2006; 72(1):75–80, Dawood et al. Br Dent J. 2009; 207(1):23–8

Image Display

Sagittal Coronal Axial

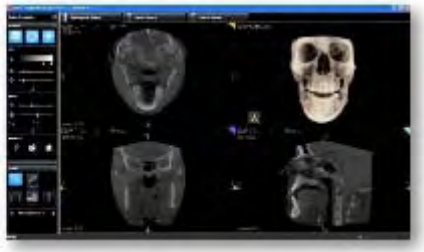


The CBCT volumetric data set is usually reconstructed in orthogonal orientations to allow viewing of the images in the sagittal, coronal and axial planes.

Scarfe and Farman (Dept. of Surgical/Hospital Dentistry University of Louisville School of Dentistry), from the Summer 2007 AADMRT Newsletter

Field of View (FOV) Selection

- Large
- Medium
- Focused



- Large
- Medium
- Focused

Field of View (FOV) Selection

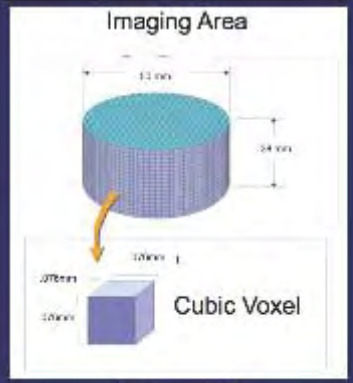
- Large
- Medium
- Focused

Medium FOV is what we order most of the time

1. Limit radiation exposure to the area of interest only – reducing radiation exposure
2. Exposure of a wide FOV places additional responsibilities on the dental practitioner

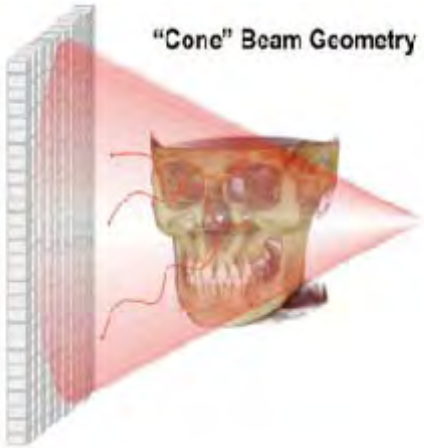
Pixel vs. Voxel

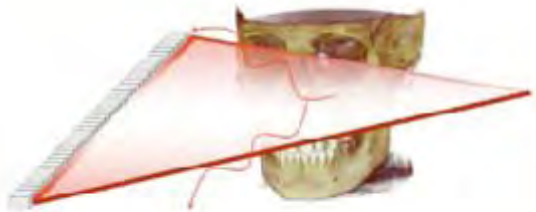
- A pixel ("picture element") is a small rectangle, anywhere from 20-60 μ
- "Pixel" in a CBCT is really a "voxel," or volume element
- Voxel (VOlume piXEL) is short for volume pixel and is the smallest "box" shaped building block of a 3-D image
- CBCT units provide voxels that are isotropic - equal in all 3 dimensions



X = Y = Z

CBCT vs. Conventional Medical CT





- High Contrast Imaging
- Faster
- Less Expensive
- Lower Dose
- Higher "Noise"

- Low Contrast Imaging
- Slower
- More Expensive
- Higher Dose
- Lower "Noise"

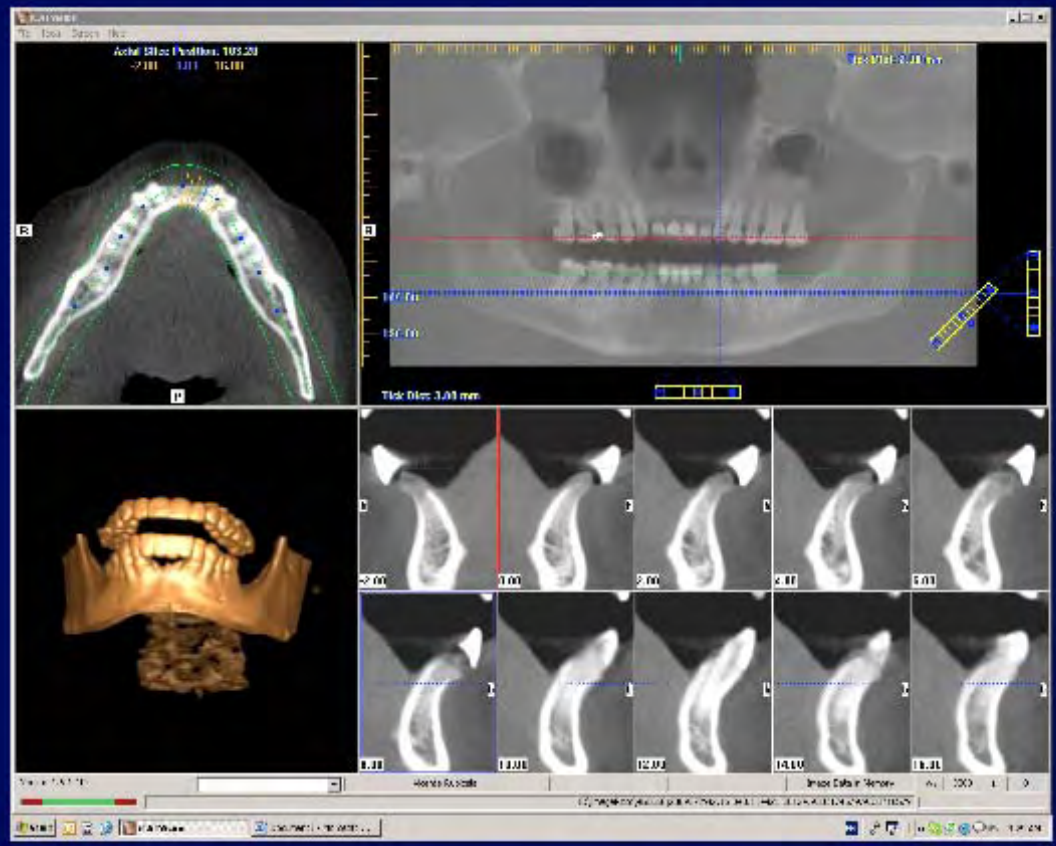
Isotropic

$x = y = z$ voxel

Anisotropic

$x = y \neq z$ voxel

I-CAT Image



I-CAT vision allows us to measure linear distances on these cross sectional images.

Why Should We Use CBCT?

- Image Accuracy: CBCT imaging produces images with sub-mm isotropic voxel resolution. Because of this characteristic, subsequent secondary images (MPR) achieve a level of spatial resolution that is accurate enough for measurement in the maxillofacial region.
- Rapid scan time: ~20 secs
- Low Radiation Dose: Beam limitation (FOV can be selected)
- Low Cost: 20-25% of the cost of conventional CT scans
- Interactive Display Modes - unique images demonstrating features in 3D that intra-oral, panoramic and cephalometric images cannot.

Where Is the CBCT Being Used?

- **Implantology**: Planning; Surgical guidance template….
- **Orthodontics**: Miniscrews; Cephalometry; Tooth position….
- **Maxillofacial Pathology/Surgery**: TMJ disorders; Odontogenic cysts & tumors; Oral cancer; Osteomyelitis; Bisphosphonate related ONJ; Orthognathic surgery; Traumatology…..
- **Dento-alveolar**: Impacted teeth; Supernumerary teeth; Root resorption; Foreign body….

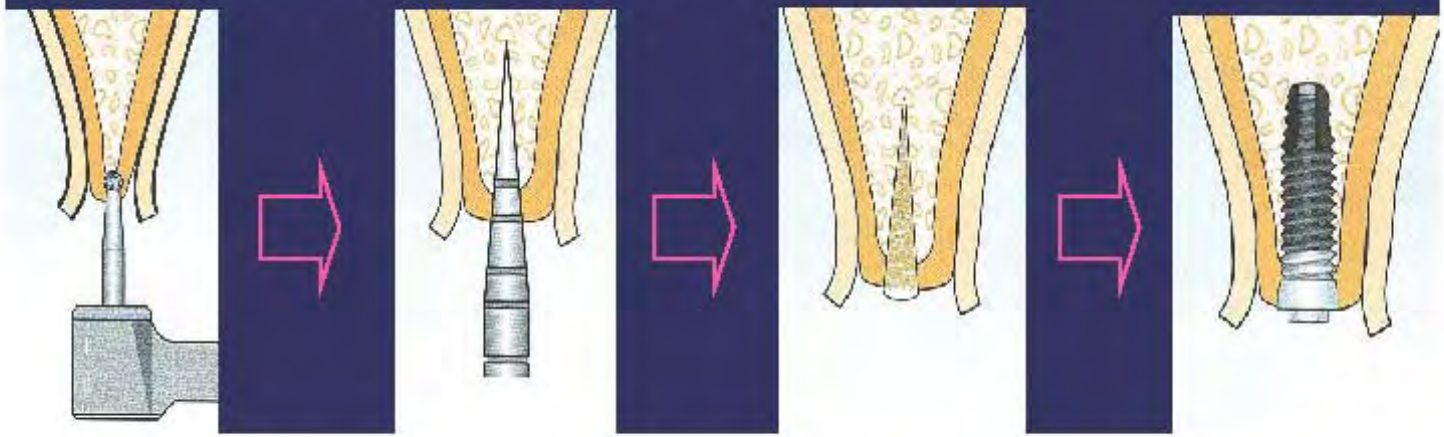
When Should We Order One?

- In a position paper by the American Academy of Oral and Maxillofacial Radiology, Tyndall and Brooks recommended that cross-sectional tomography should be the method of choice for most implant patients.
- Nevertheless, the authors stated that currently there is no scientific evidence for their recommendation because the overall success rate for dental implants is high even without the use of imaging in multiple planes.
- The ideal goal of the radiographic examination is to achieve as much information as possible and at the same time minimize the radiation burden to the patient regarding the ALARA principle and the costs
- The selection of the radiologic technique should be based on weighing the required image quality against the radiation risks and costs involved.

CBCT should be reserved for only anatomically difficult cases or where extensive implant treatment is needed

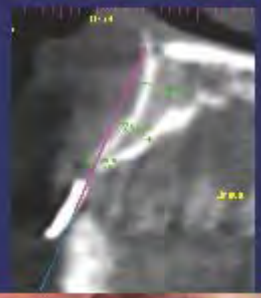
Ridge-split: Conventional Technique

1. Instruments: A). small round bur; B). oscillating saws, thin small chisel, mallet and osteotomes
2. Surgical complications: soft tissue (gingiva, lips and/or tongue) encroachments, thermal injury during osteotomy, or cortical plate fracture.
3. Fear and stress during instrumentation due to unpleasant noises and macrovibrations.



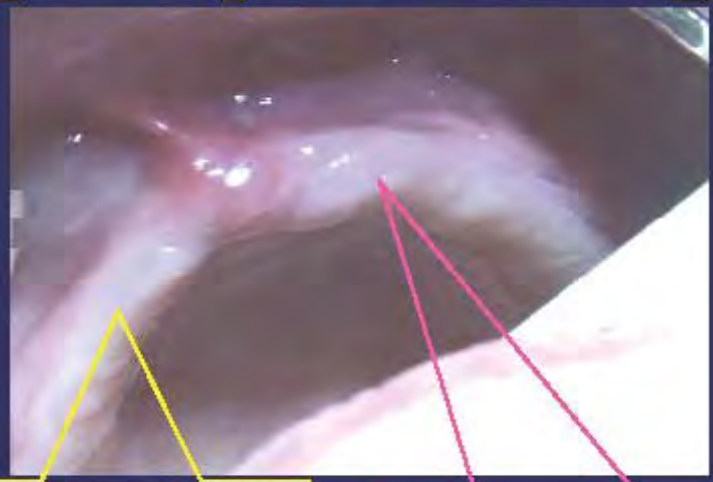
Segmental Ridge-split Surgery

Originally developed by Simion et al. (1992) and Scipioni et al. (1994), and later discussed by Nevins and Stein (1998).



Coatoam GW, Mariotti A. The segmental ridge-split procedure. J Periodontol 2003; 74:757-770.

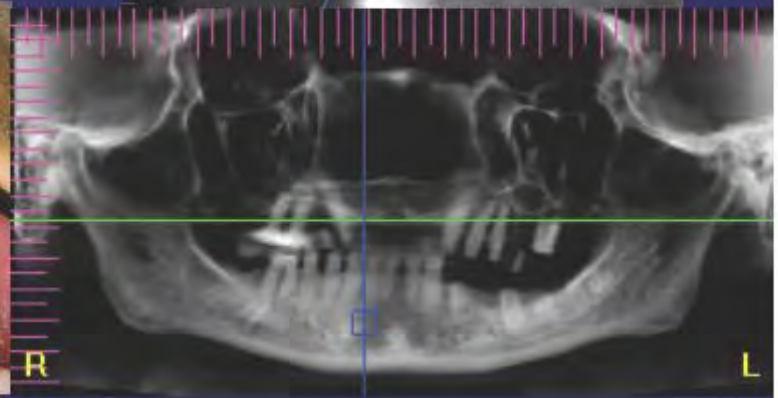
Ridge Split Surgery



Ridge Split Surgery

Osteotome Expansion

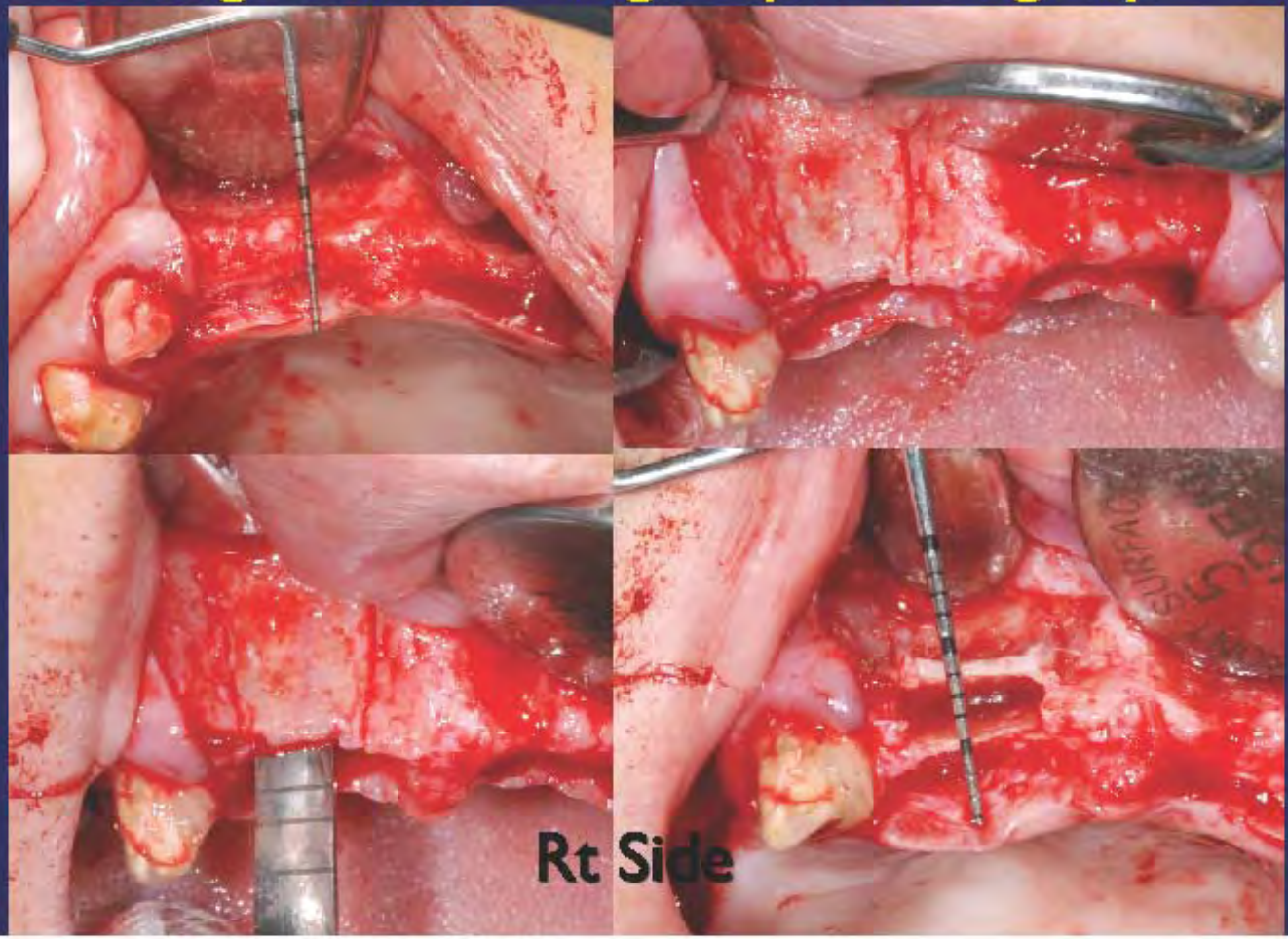
Segmental Ridge-split Surgery



Rt Side

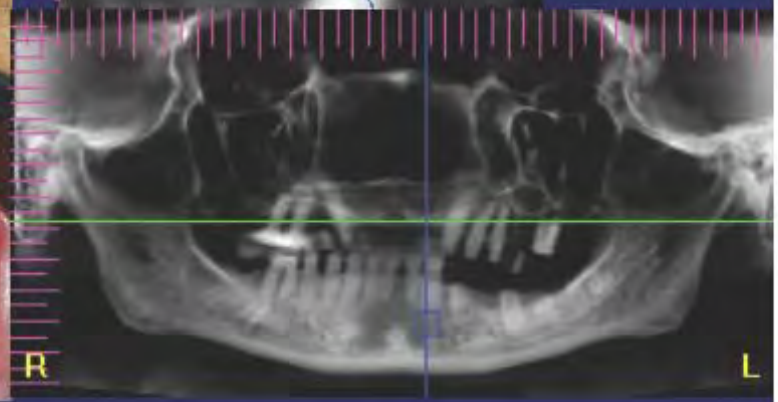
Surgical Stent with GP point

Segmental Ridge-split Surgery

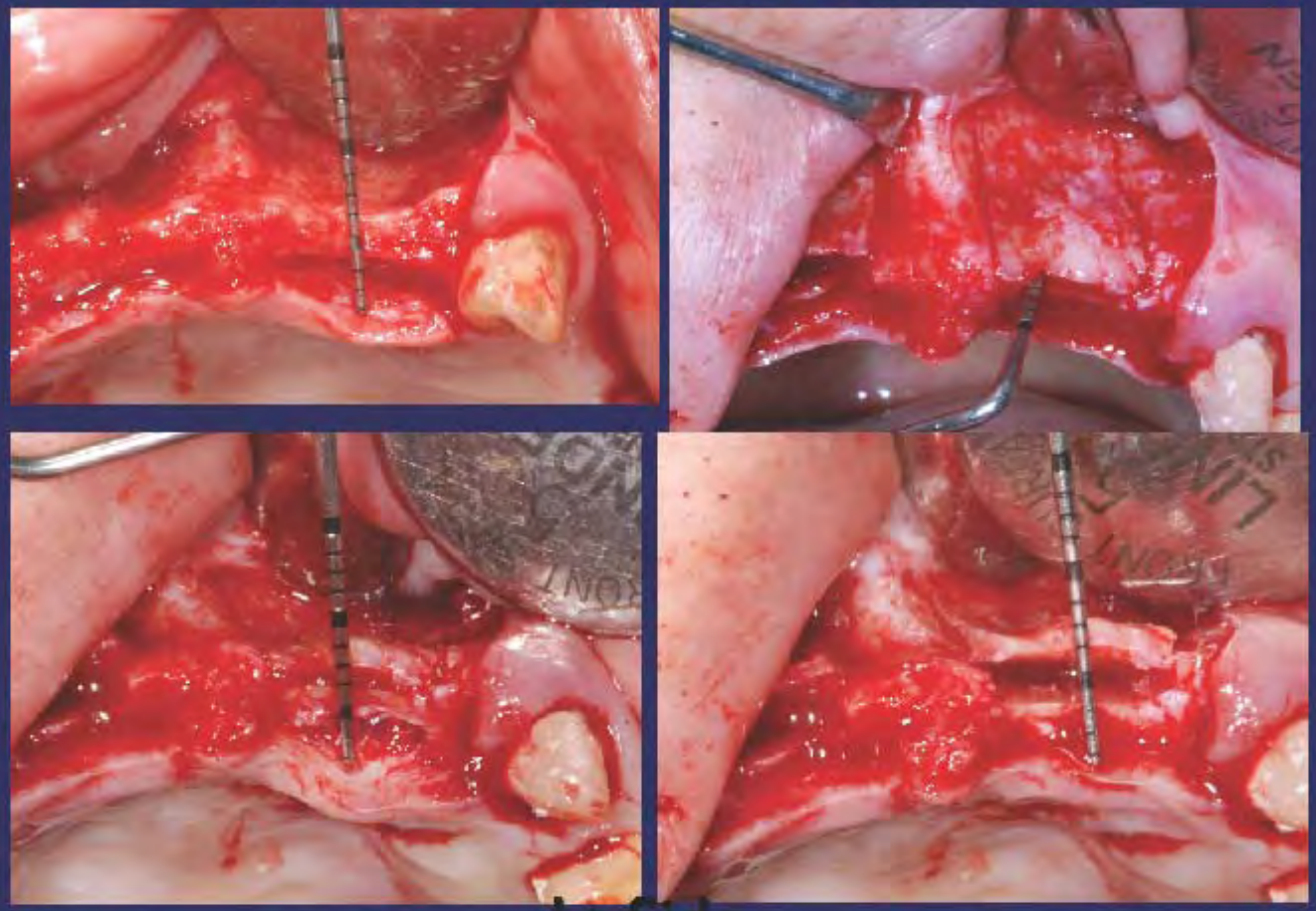


Segmental Ridge-split Surgery

Lt Side

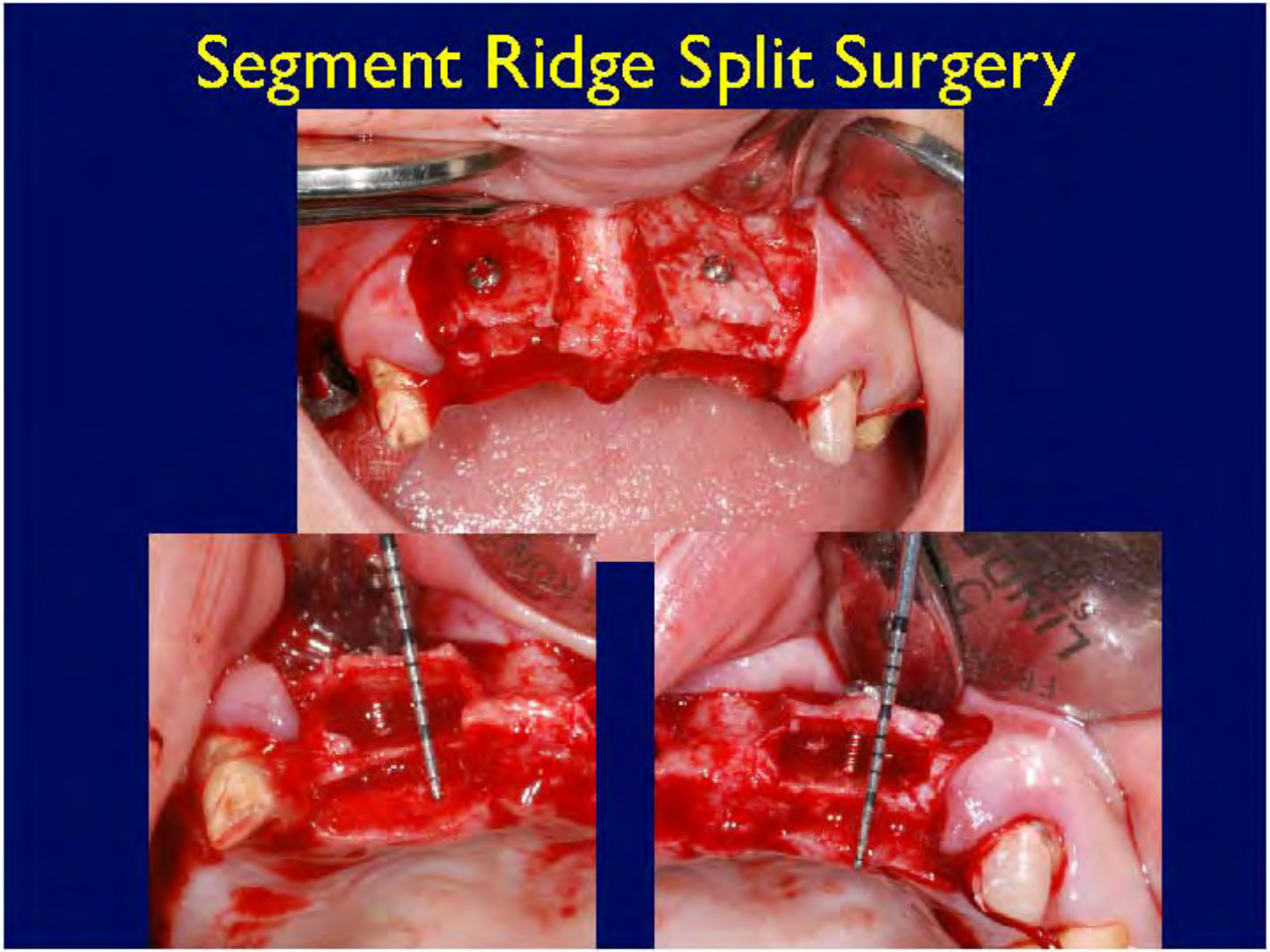


Segment Ridge Split Surgery

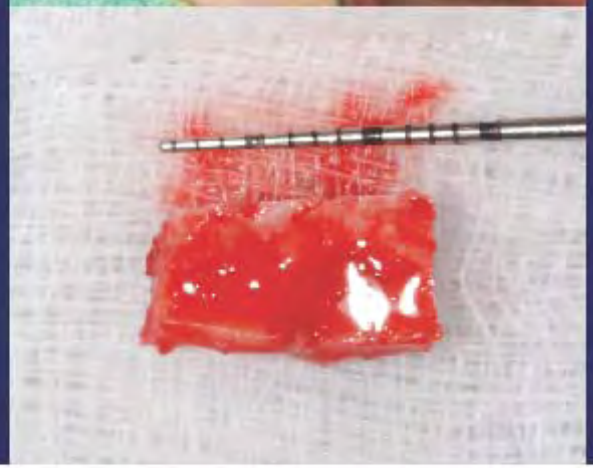


Lt Side

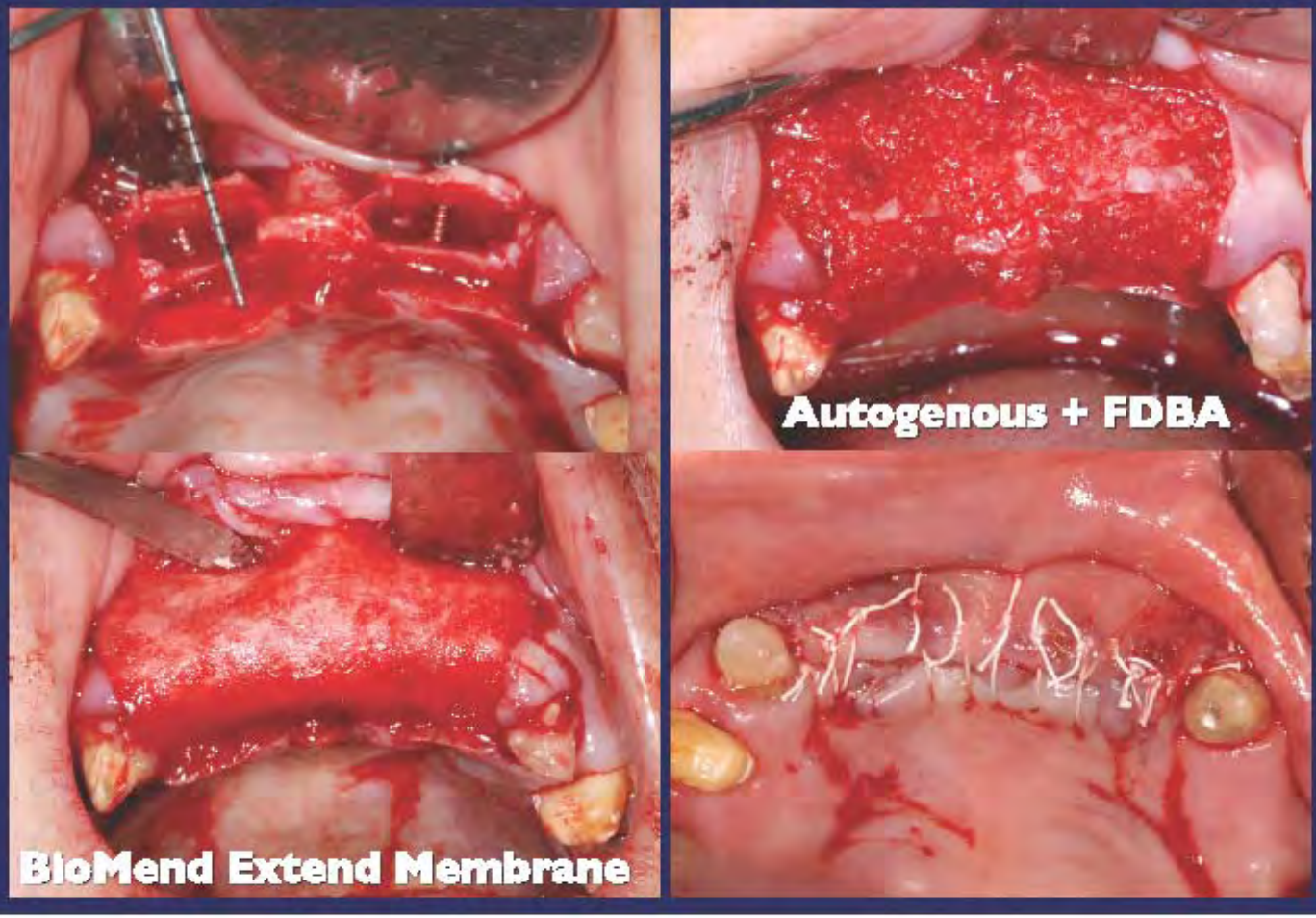
Segment Ridge Split Surgery



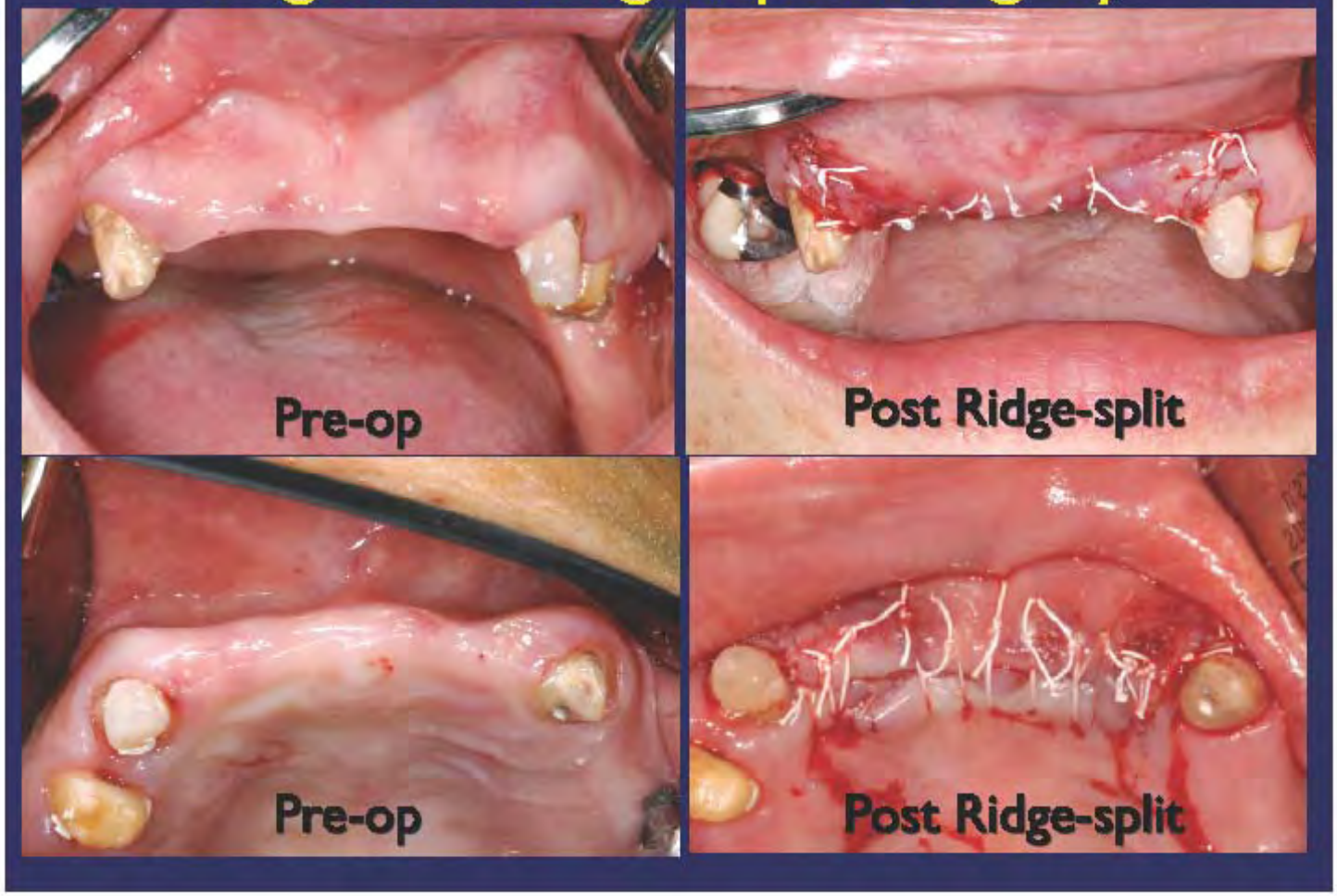
Autogenous Bone Obtained From Mandibular Ramus

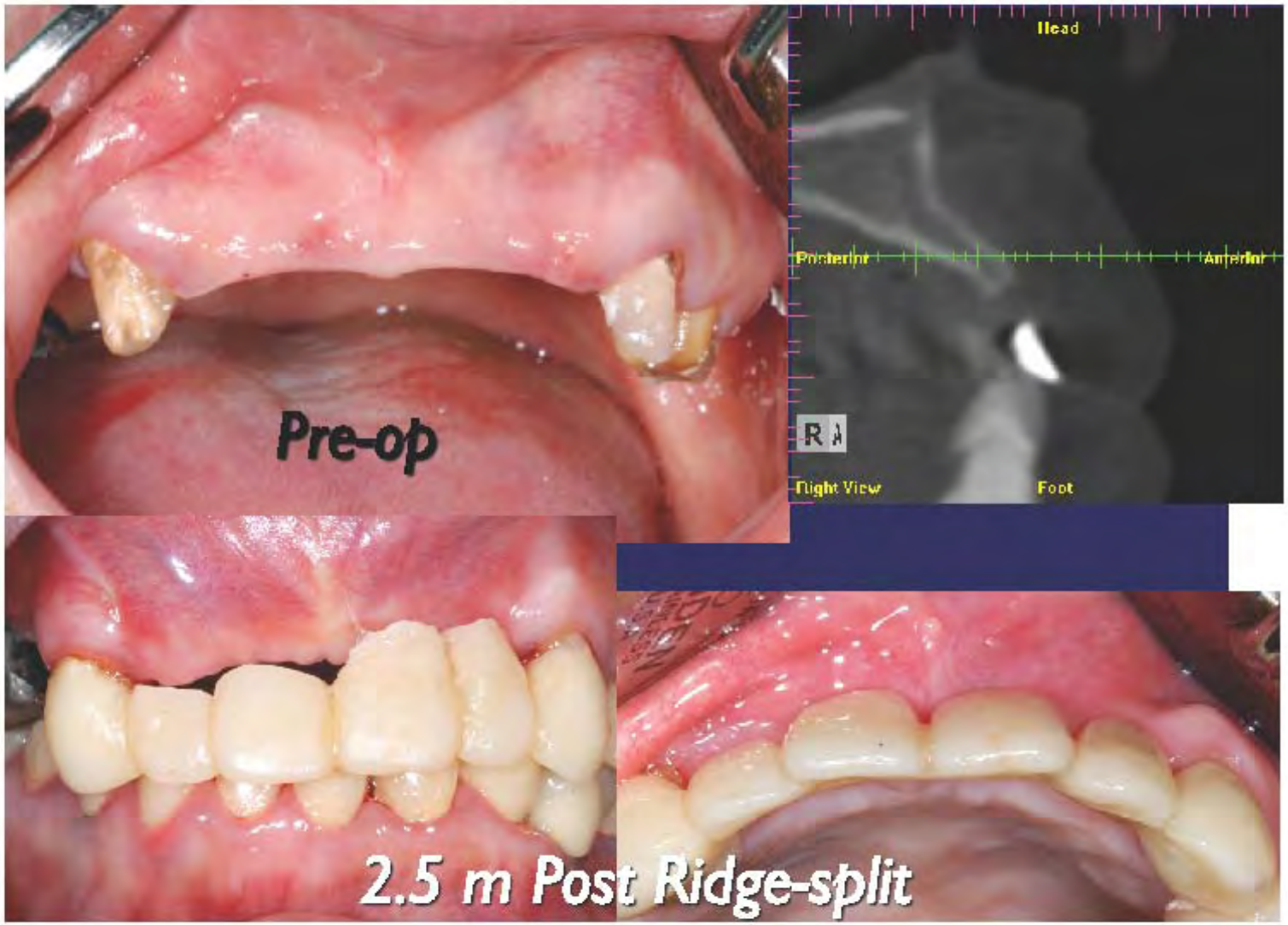


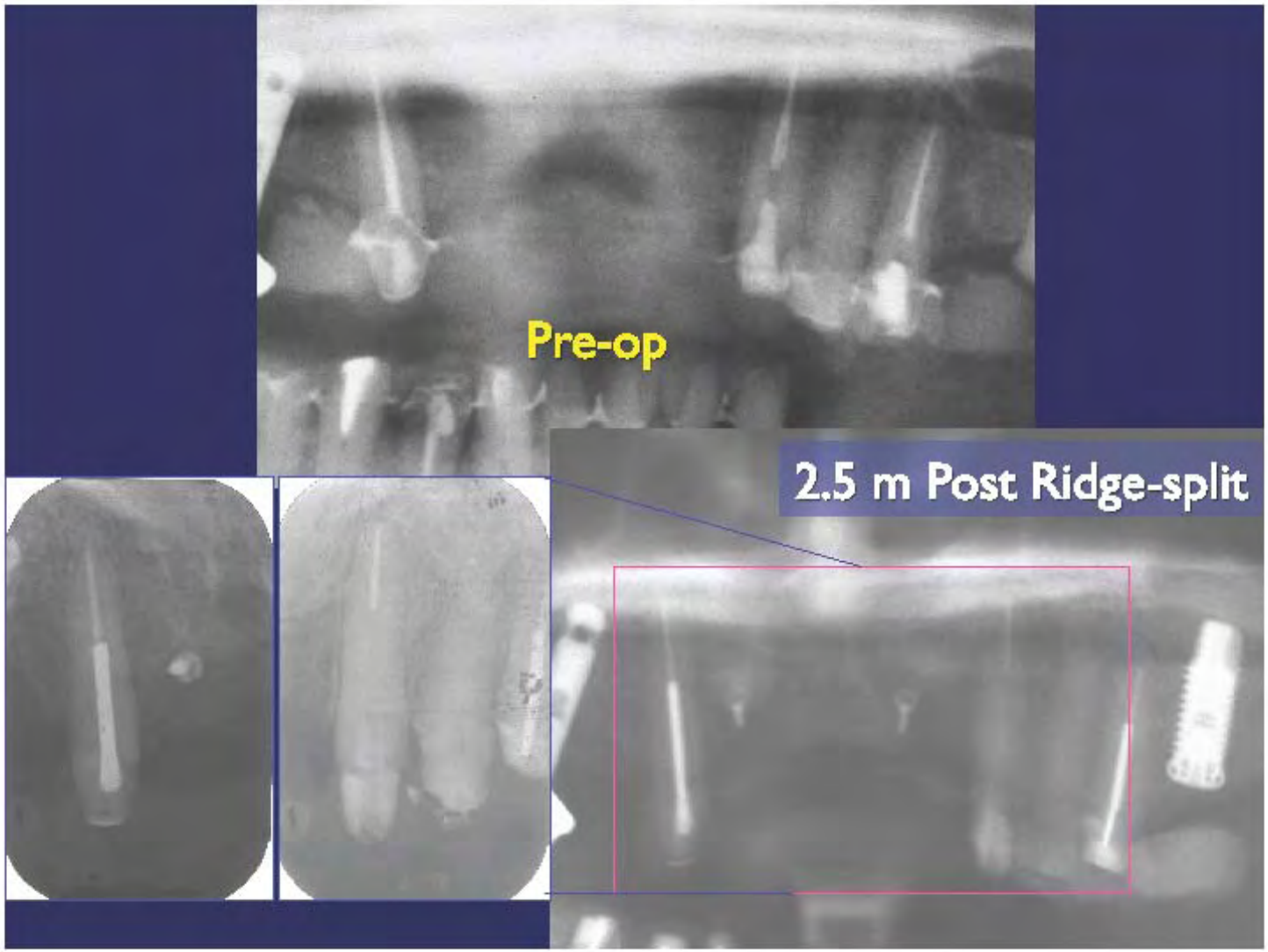
Segment Ridge Split Surgery

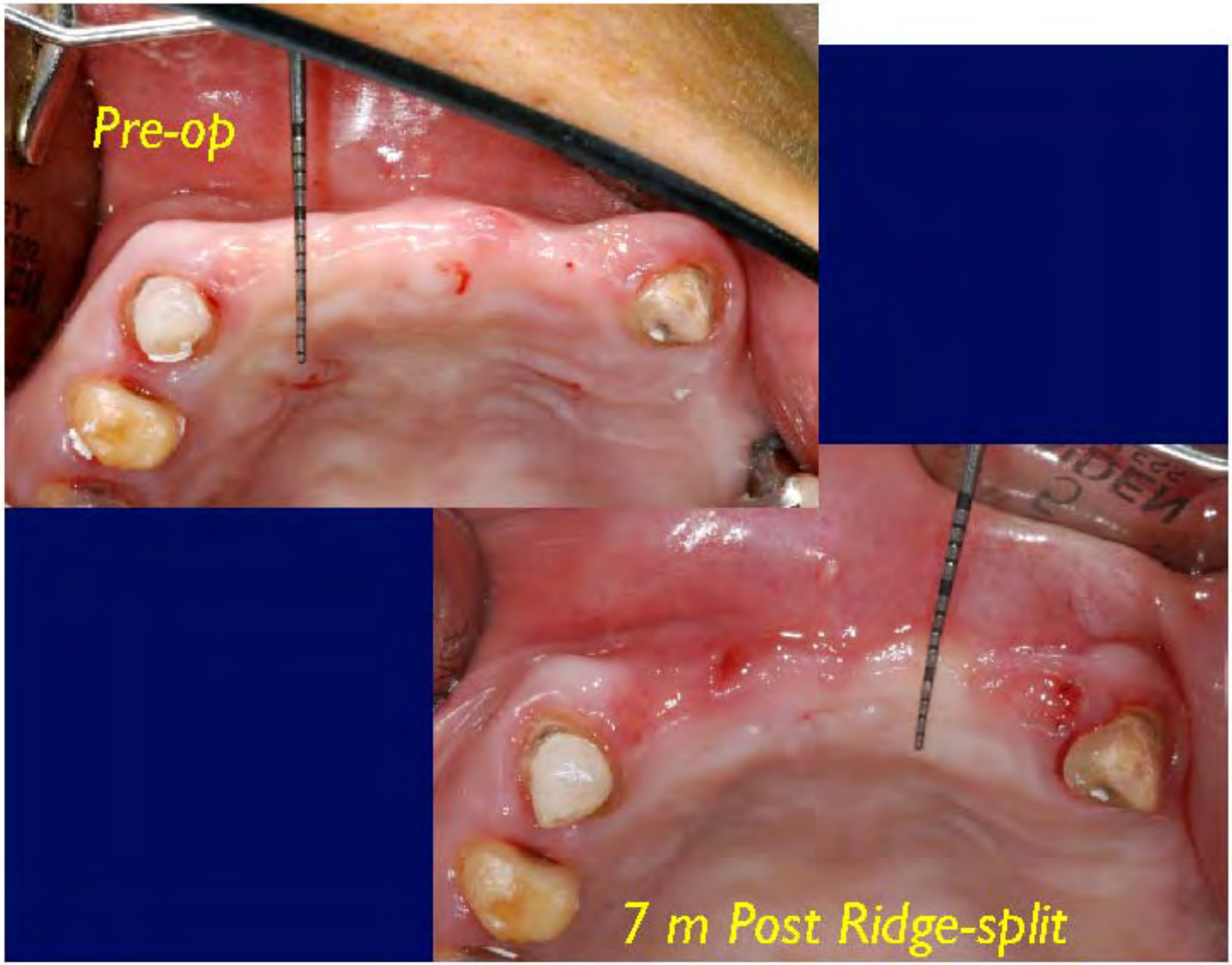


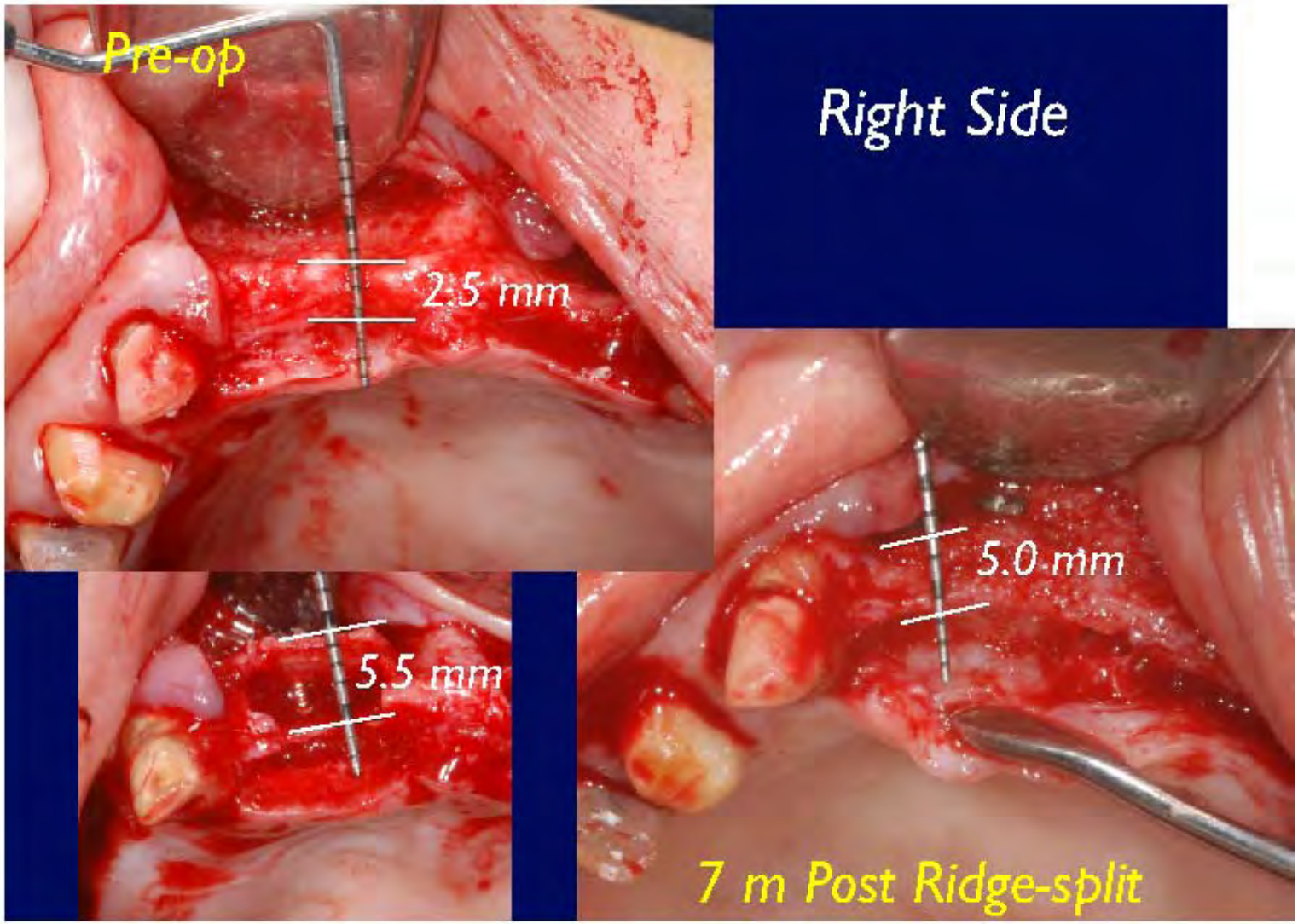
Segment Ridge Split Surgery

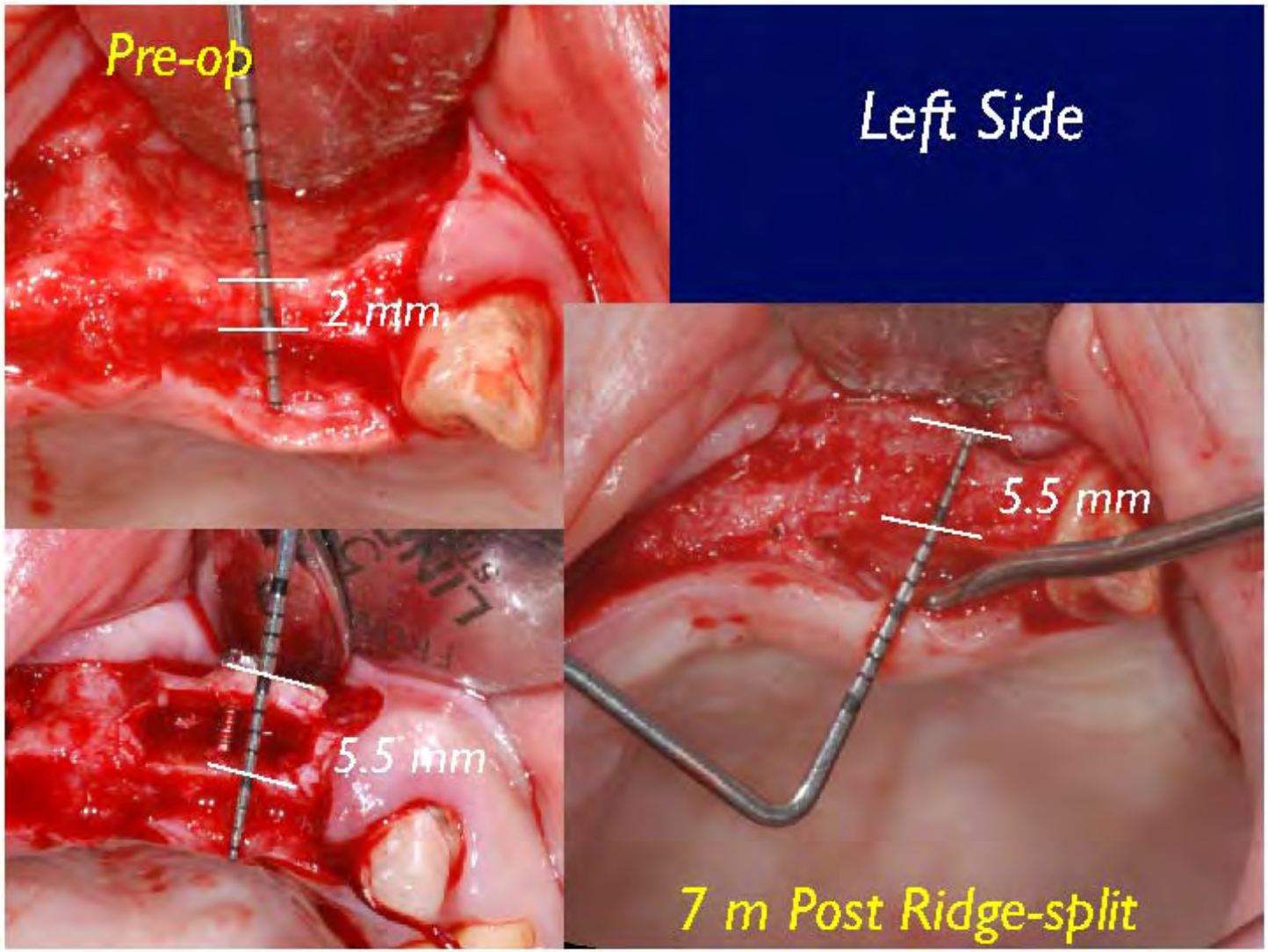


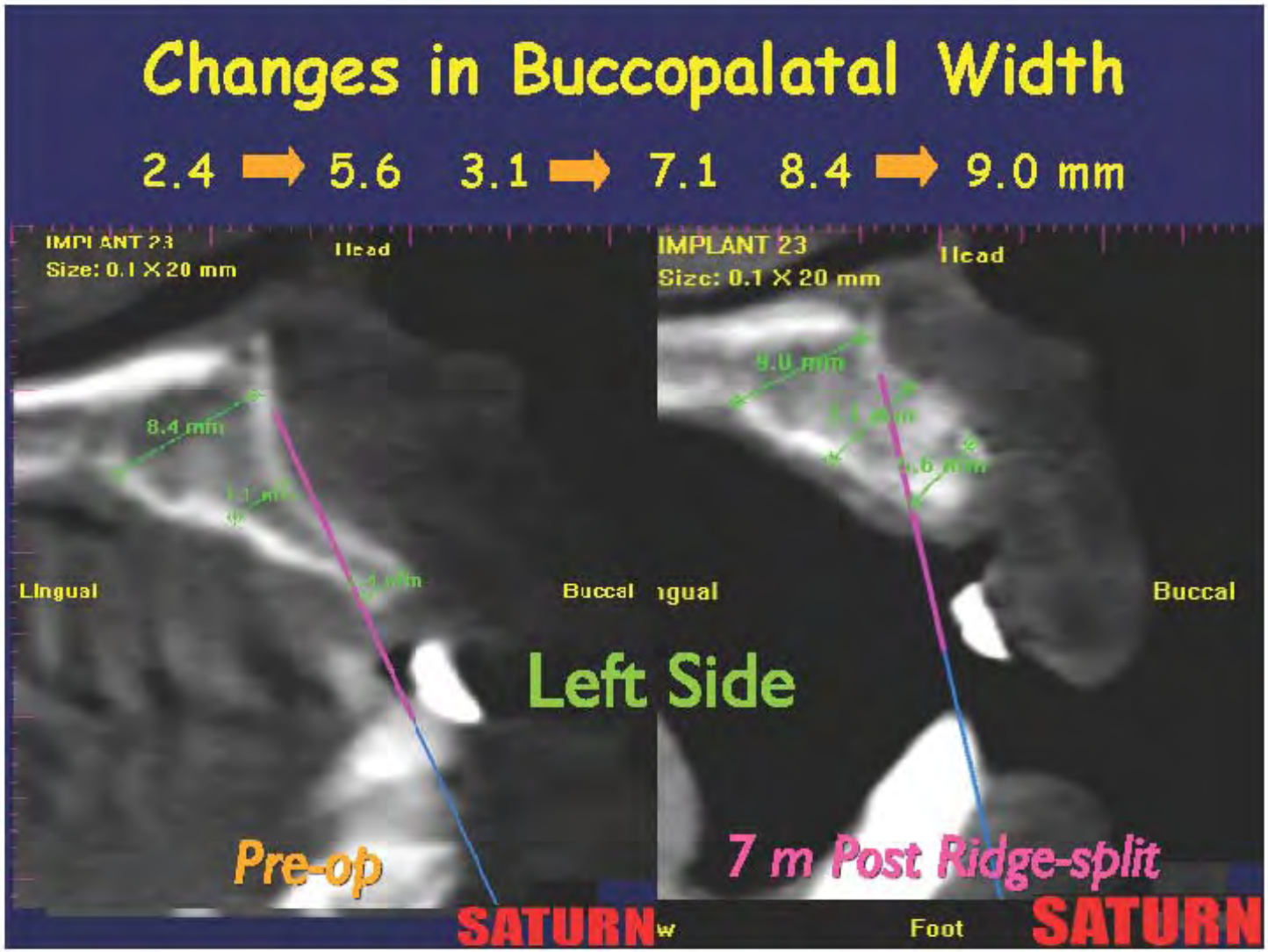

Pre-op
Head
Posterior
Anterior
Right View
Foot
2.5 m Post Ridge-split

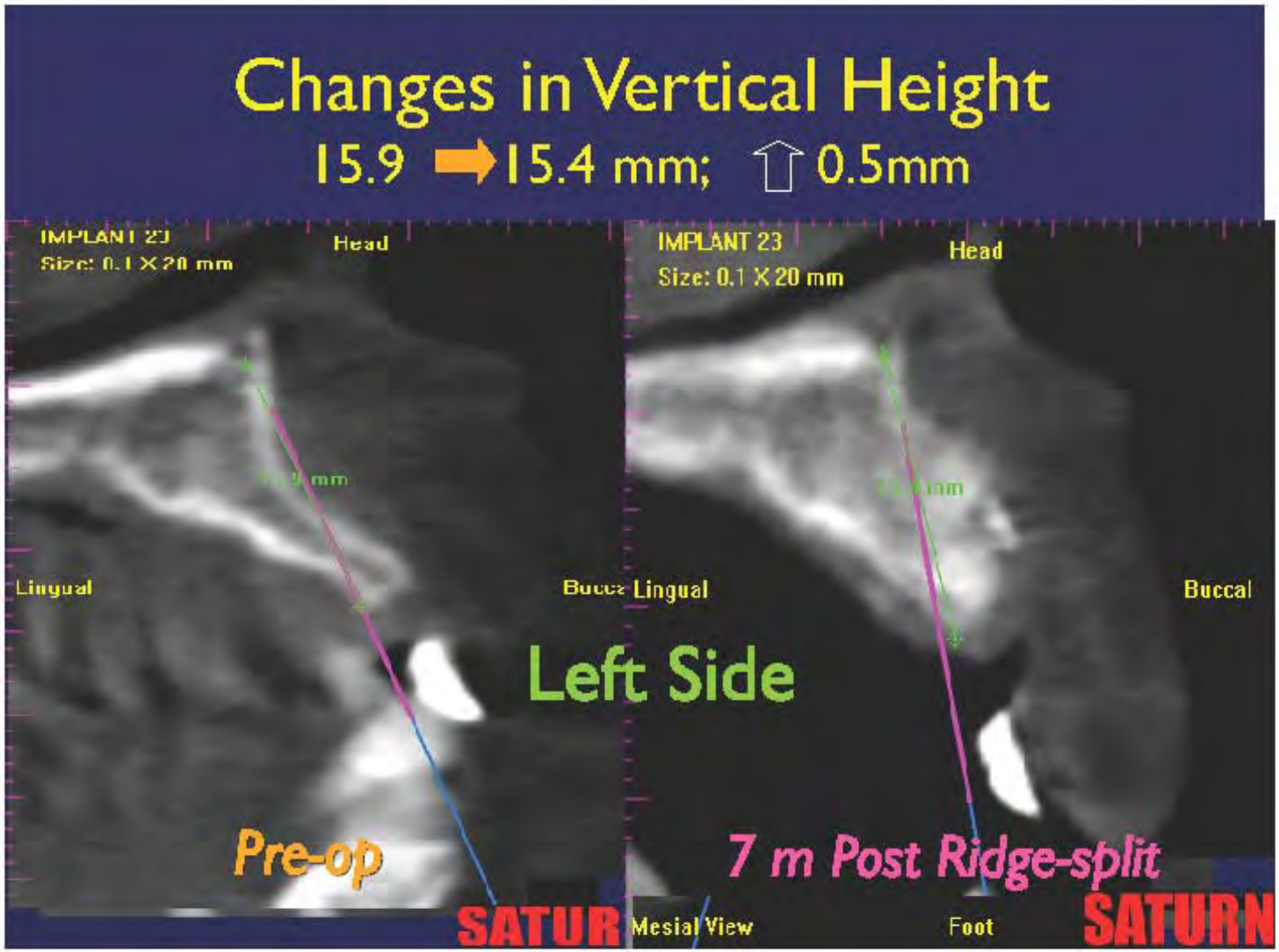

Pre-op
2.5 m Post Ridge-split


Pre-op
7 m Post Ridge-split


Pre-op
2.5 mm
Right Side
5.0 mm
5.5 mm
7 m Post Ridge-split

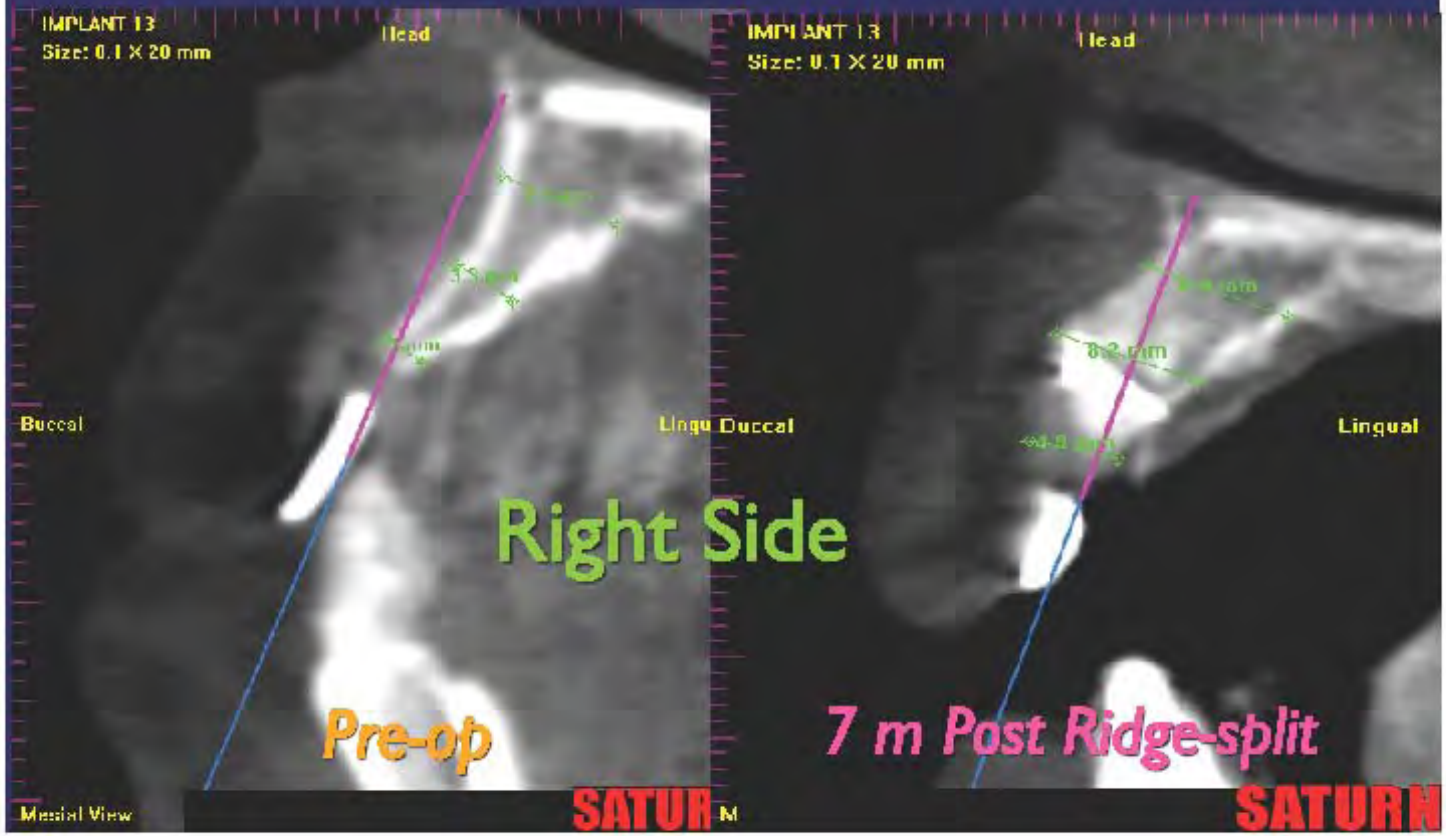

Pre-op
2 mm
Left Side
5.5 mm
5.5 mm
7 m Post Ridge-split


Changes in Buccopalatal Width
2.4 5.6 3.1 7.1 8.4 9.0 mm
IMPLANT 23
Size: 0.1 X 20 mm
Head
8.4 mm
Lingual
Buccal
Pre-op
IMPLANT 23
Size: 0.1 X 20 mm
Head
9.0 mm
Buccal
Left Side
7 m Post Ridge-split
Foot
SATURN
SATURN


Changes in Vertical Height
15.9 ➡ 15.4 mm; ⇧ 0.5mm
IMPLANT 23
Size: 0.1 X 20 mm
Head
Lingual
Buccal
Left Side
Pre-op
SATURN
IMPLANT 23
Size: 0.1 X 20 mm
Head
Lingual
Buccal
7 m Post Ridge-split
Mesial View
Foot
SATURN

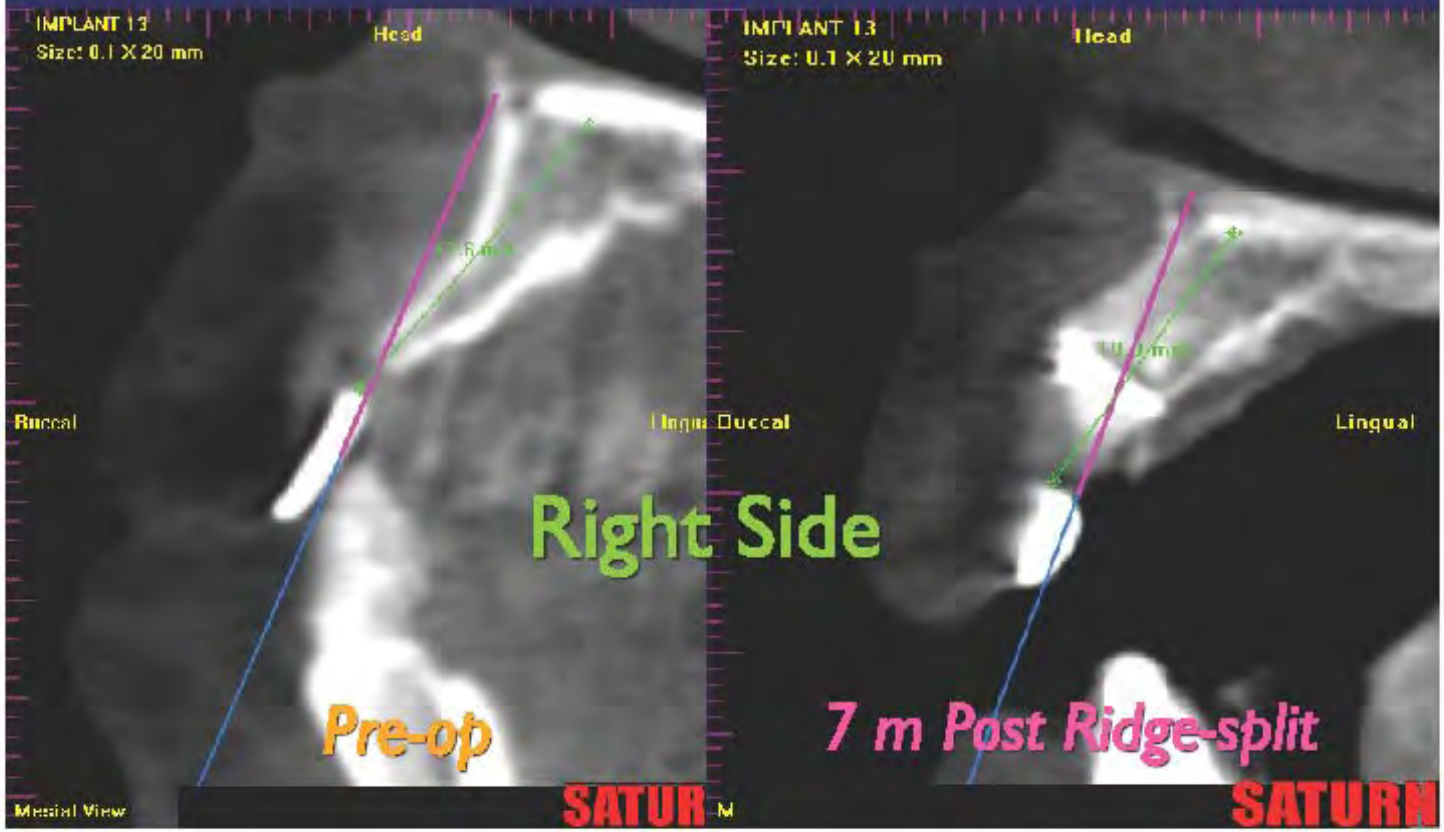
Changes in Buccopalatal Width

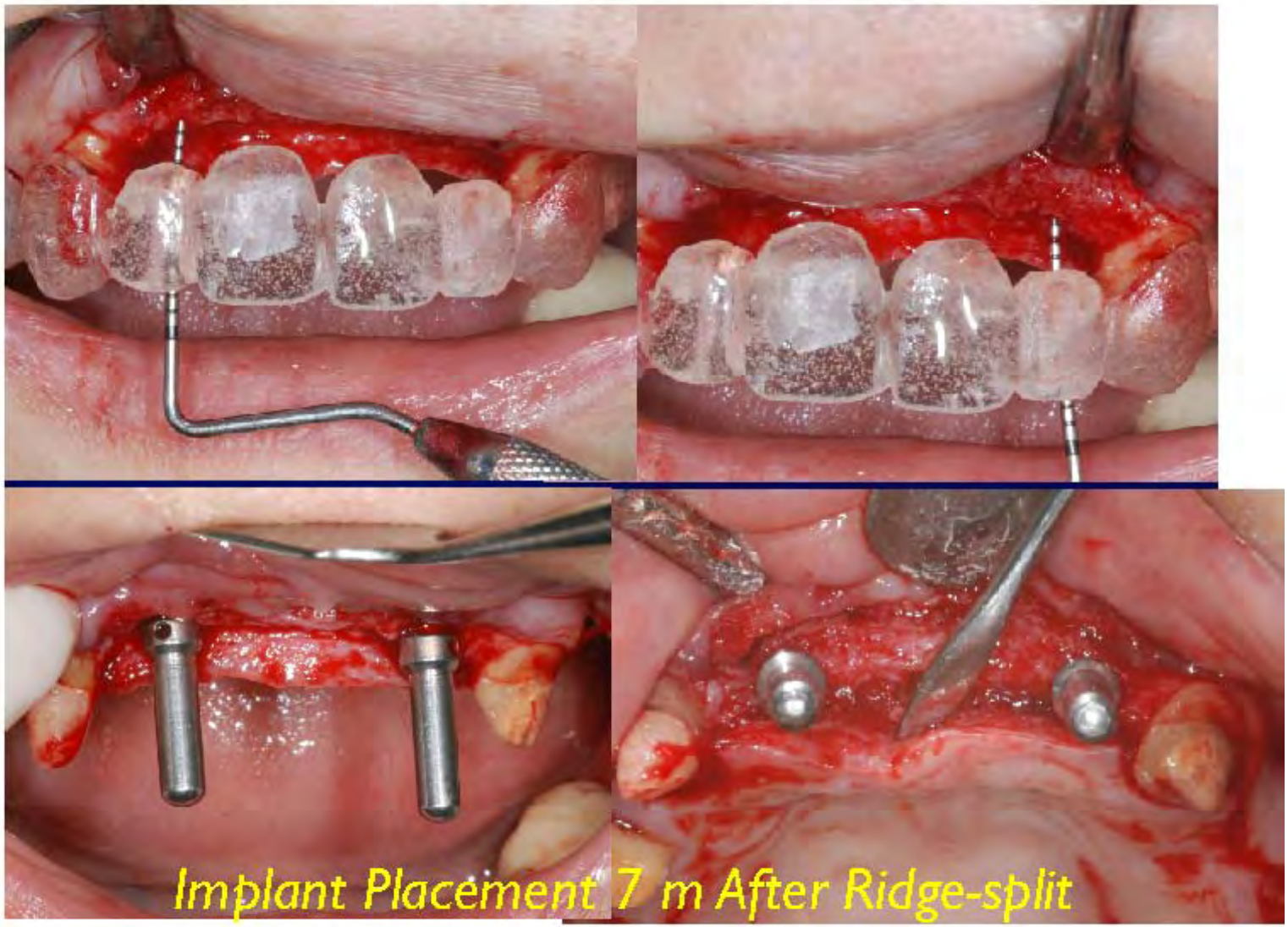
2.1 ➡ 4.9 3.3 ➡ 8.2 6.3 ➡ 8.4 mm

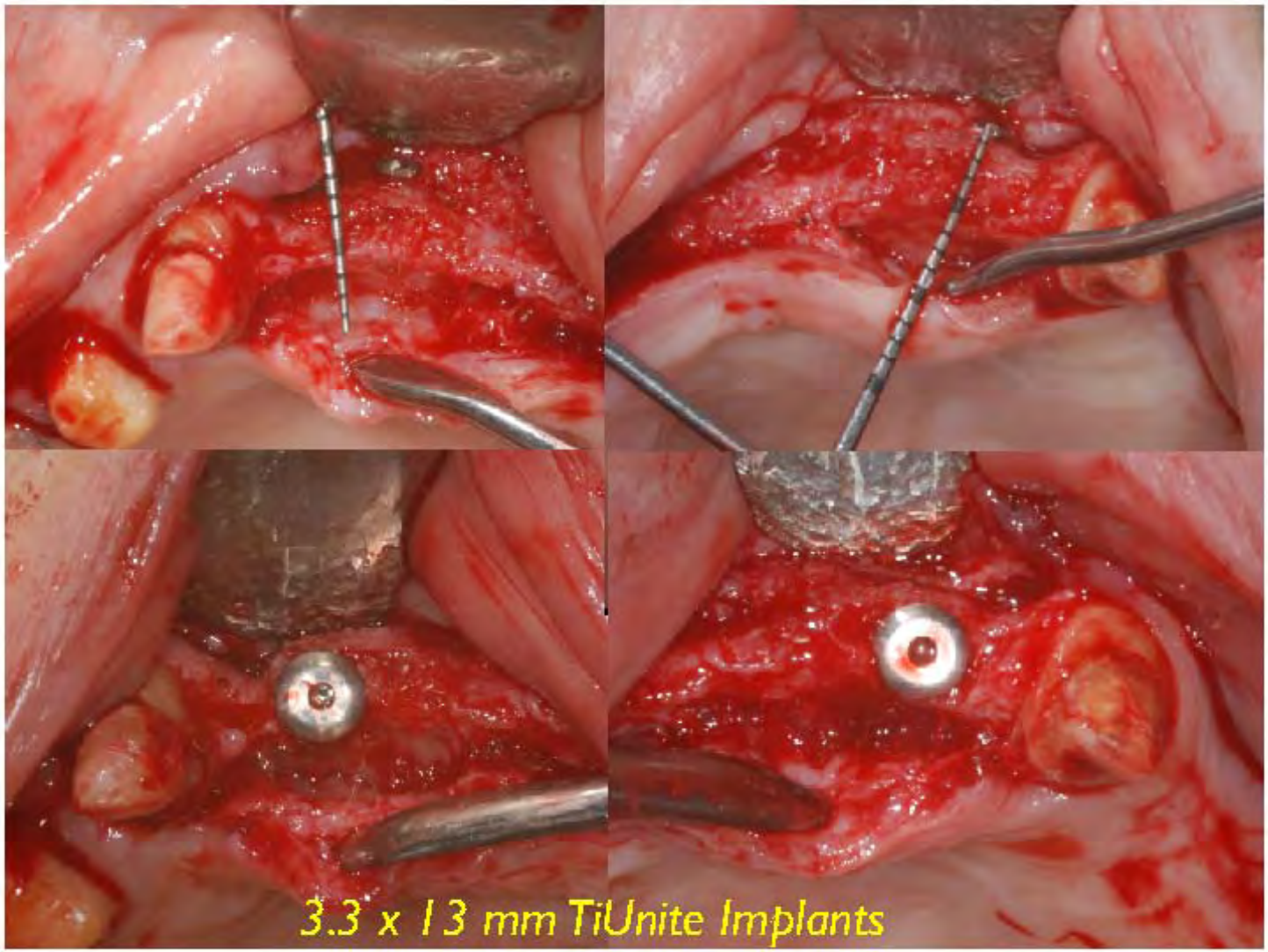


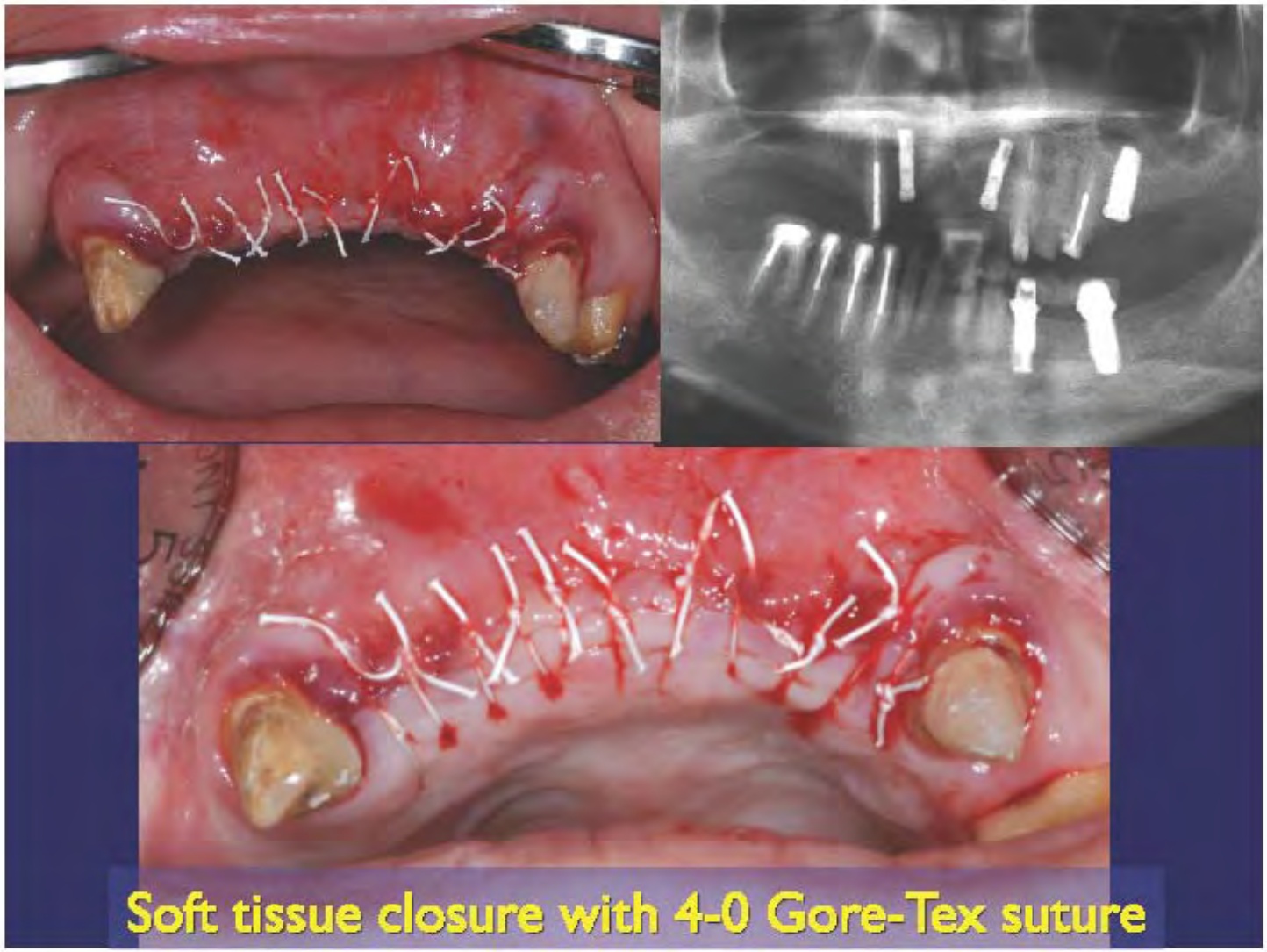
Changes in Vertical Height

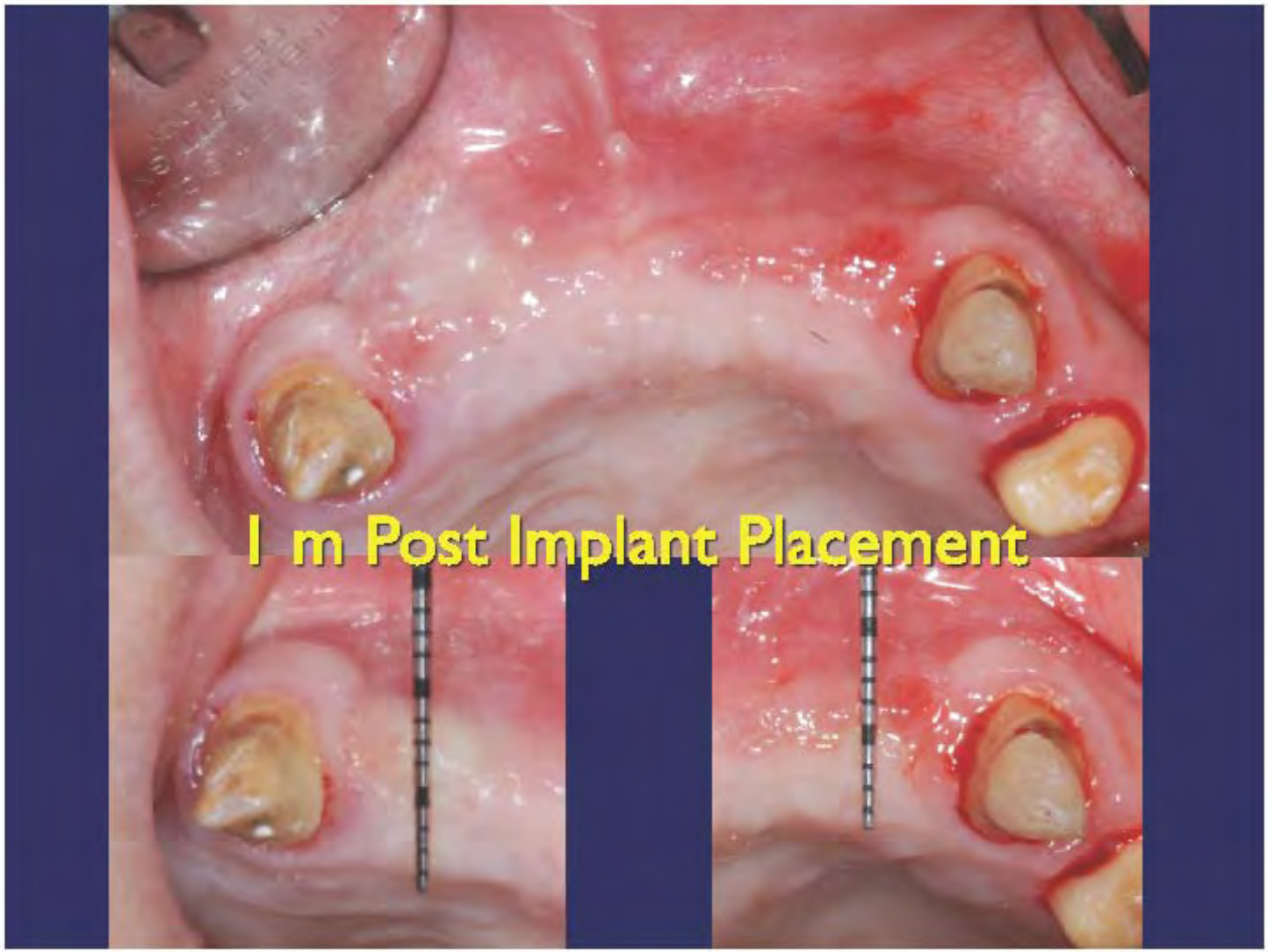
17.6 ➡ 18.3 mm; ⇧ 0.7 mm

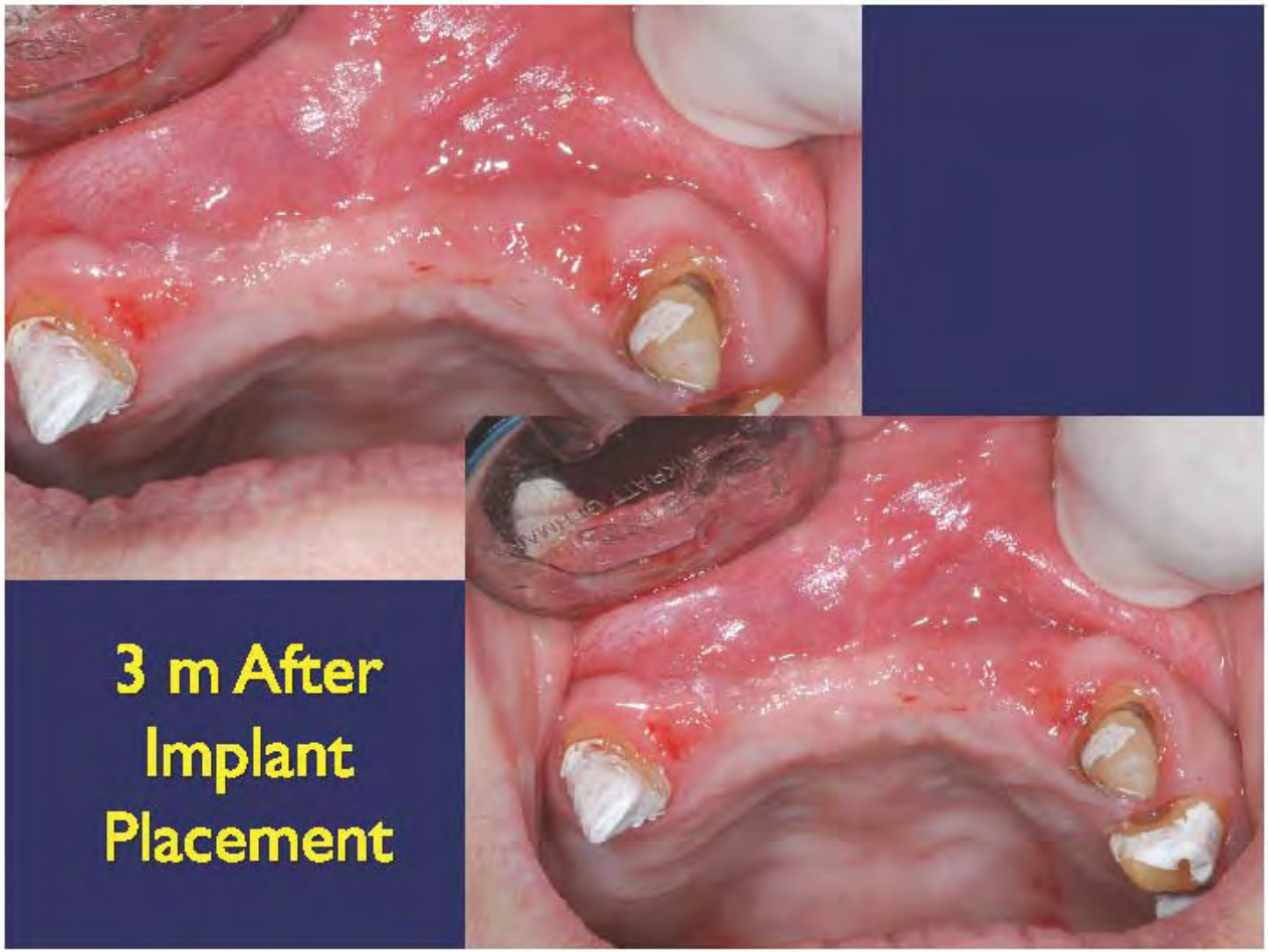



Implant Placement 7 m After Ridge-split

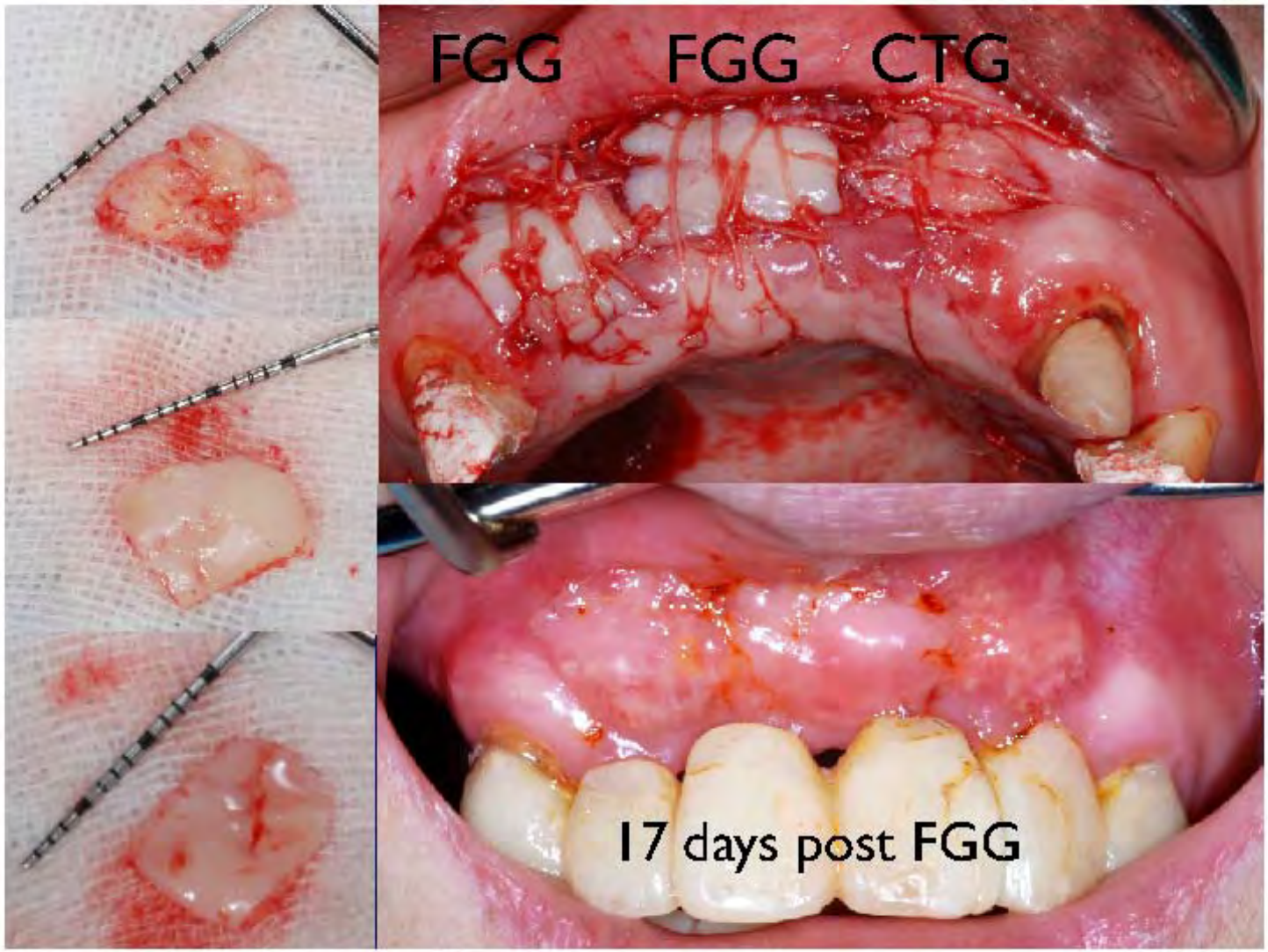

3.3 x 13 mm TiUnite Implants


Soft tissue closure with 4-0 Gore-Tex suture


I m Post Implant Placement

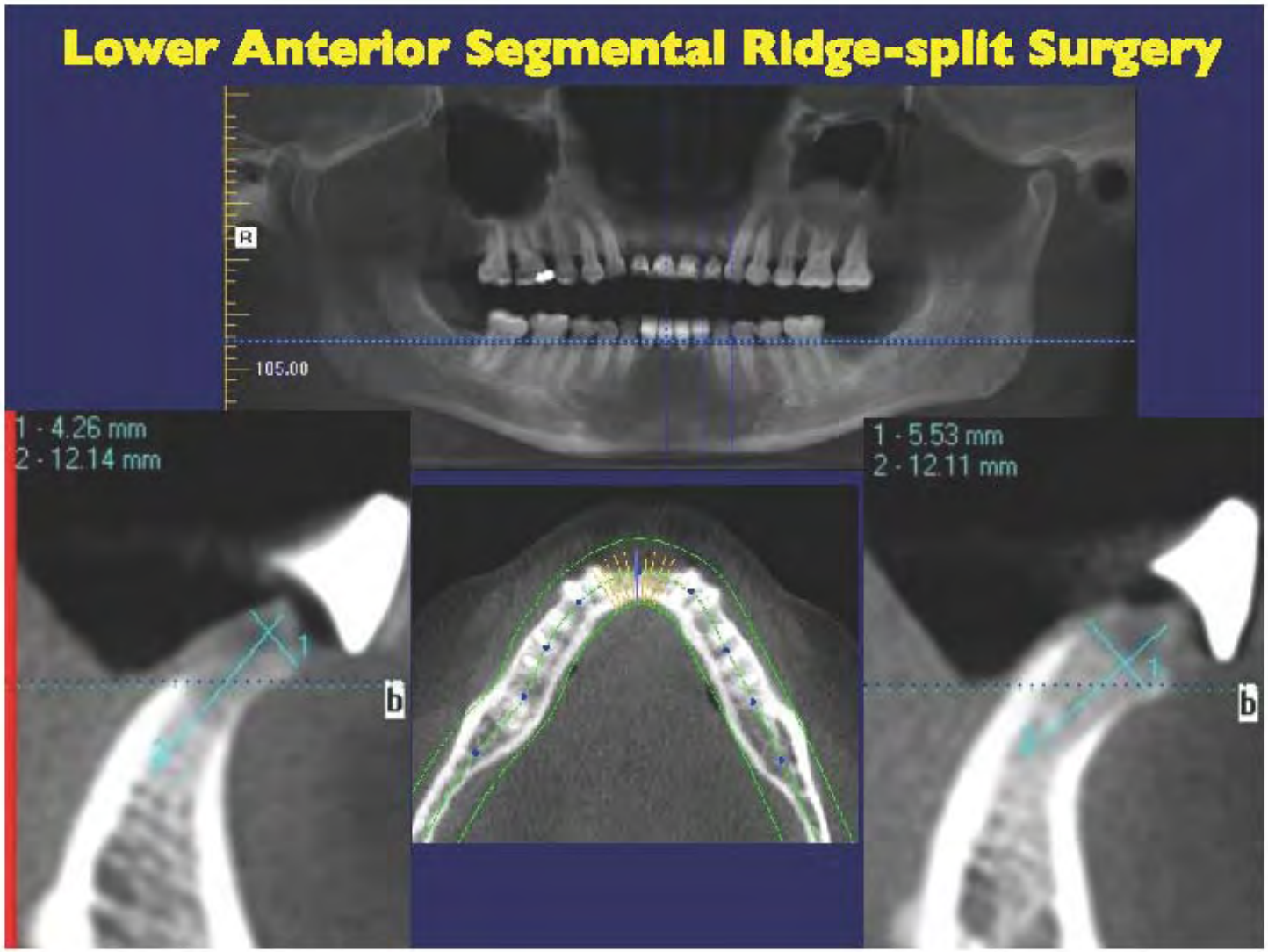

3 m After
Implant
Placement

3 m After Implant Placement

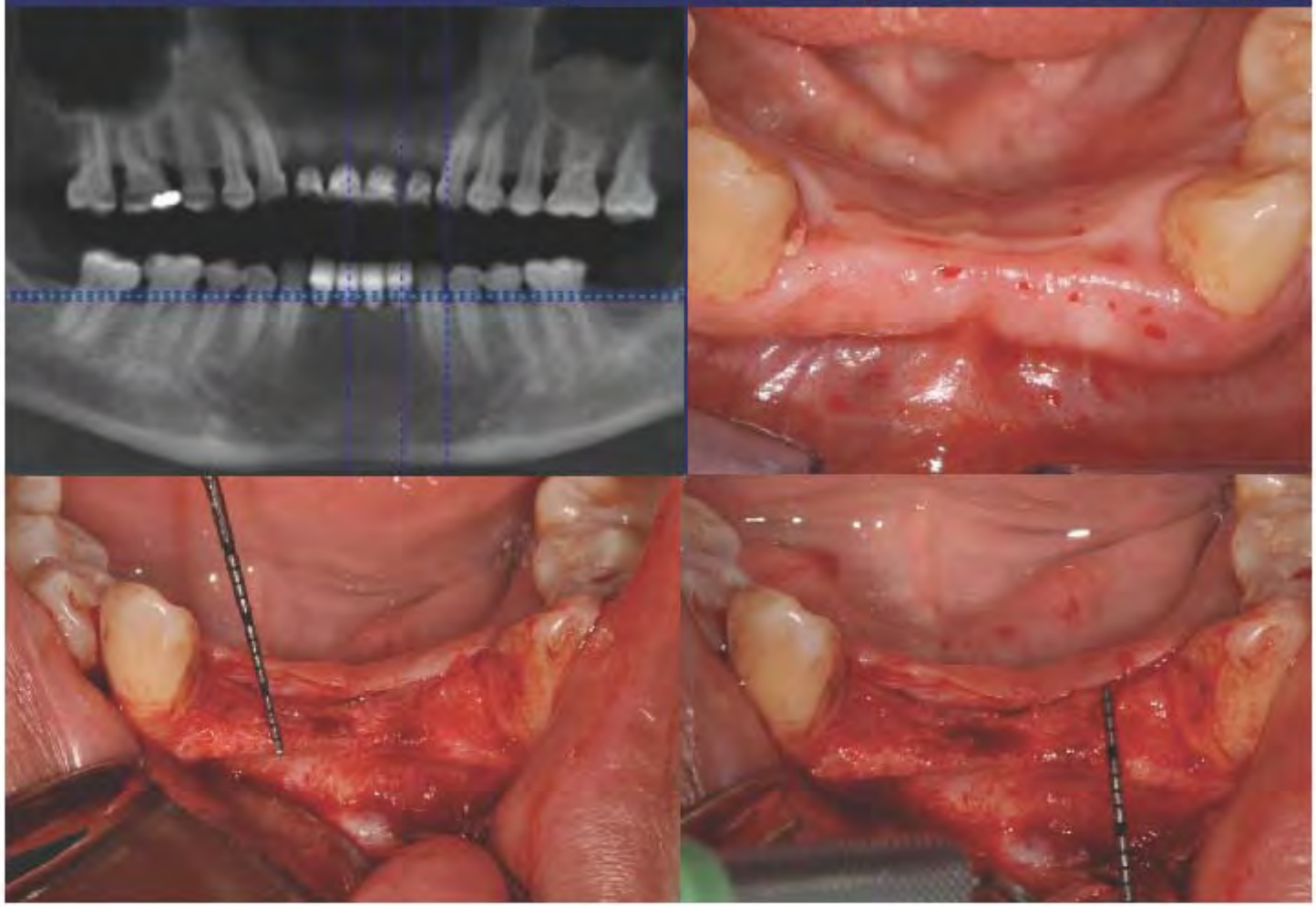

FGG
FGG
CTG
17 days post FGG

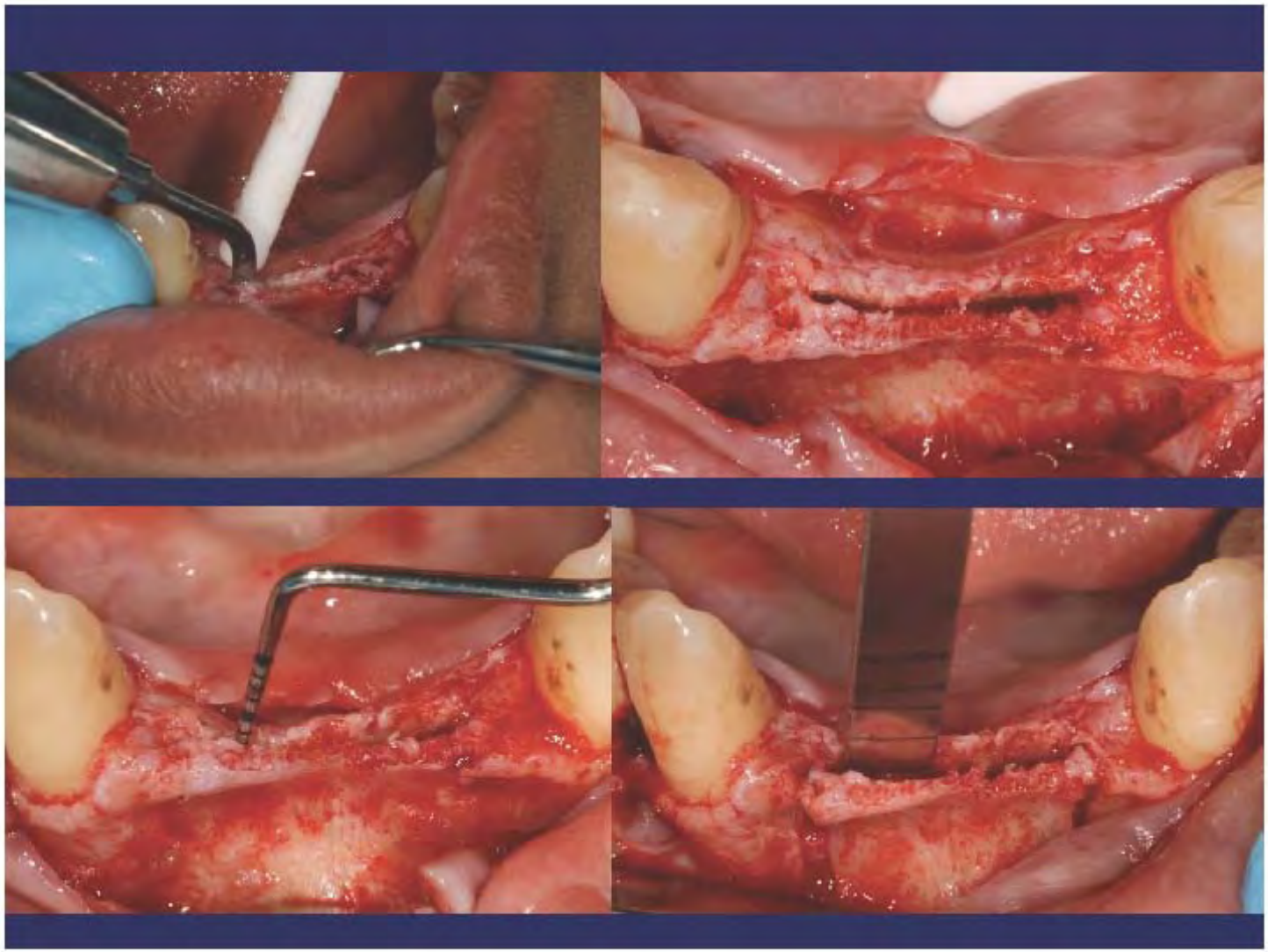

Pre-FGG
17 days post FGG

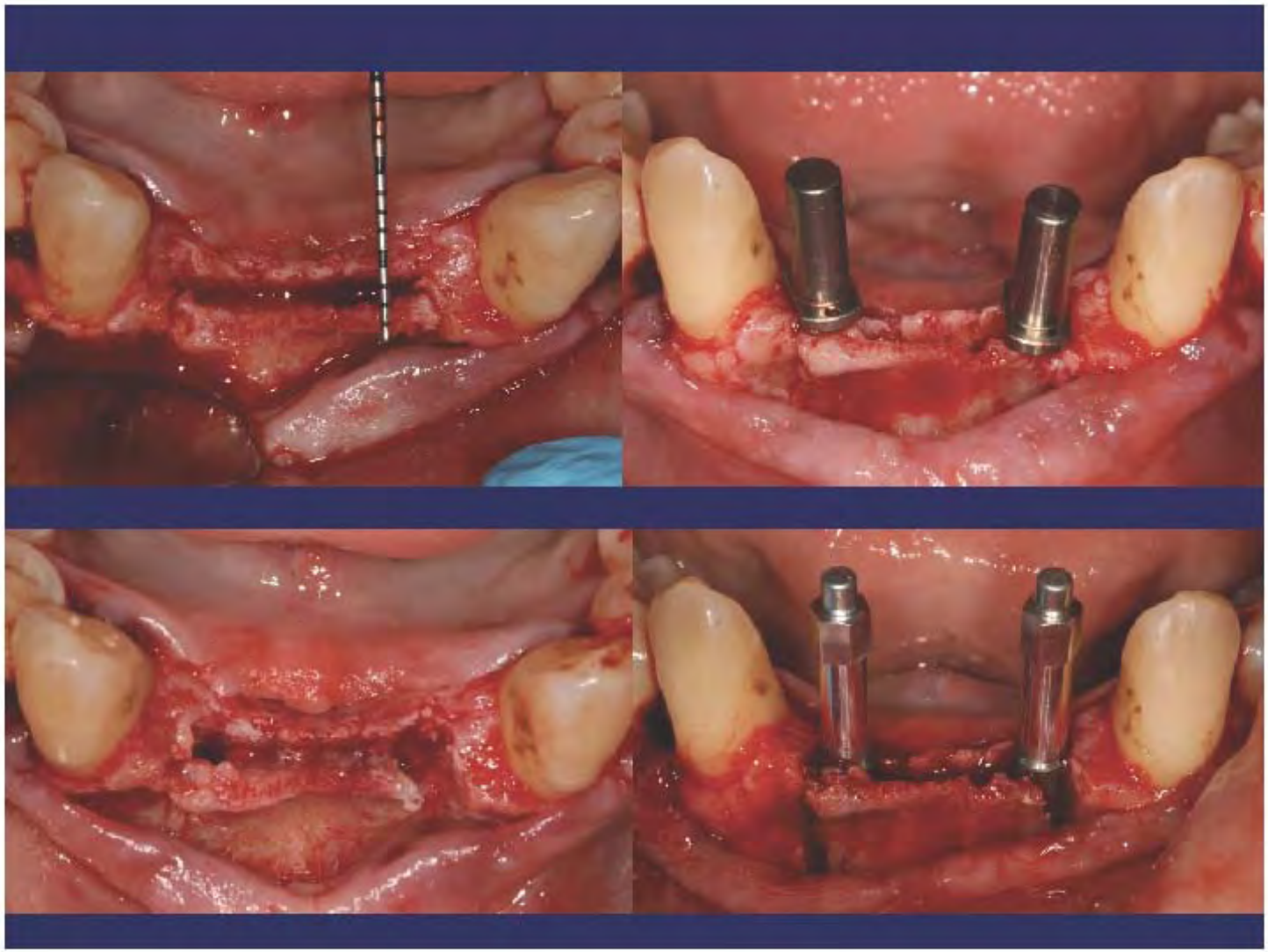
Lower Anterior Segmental Ridge-split Surgery

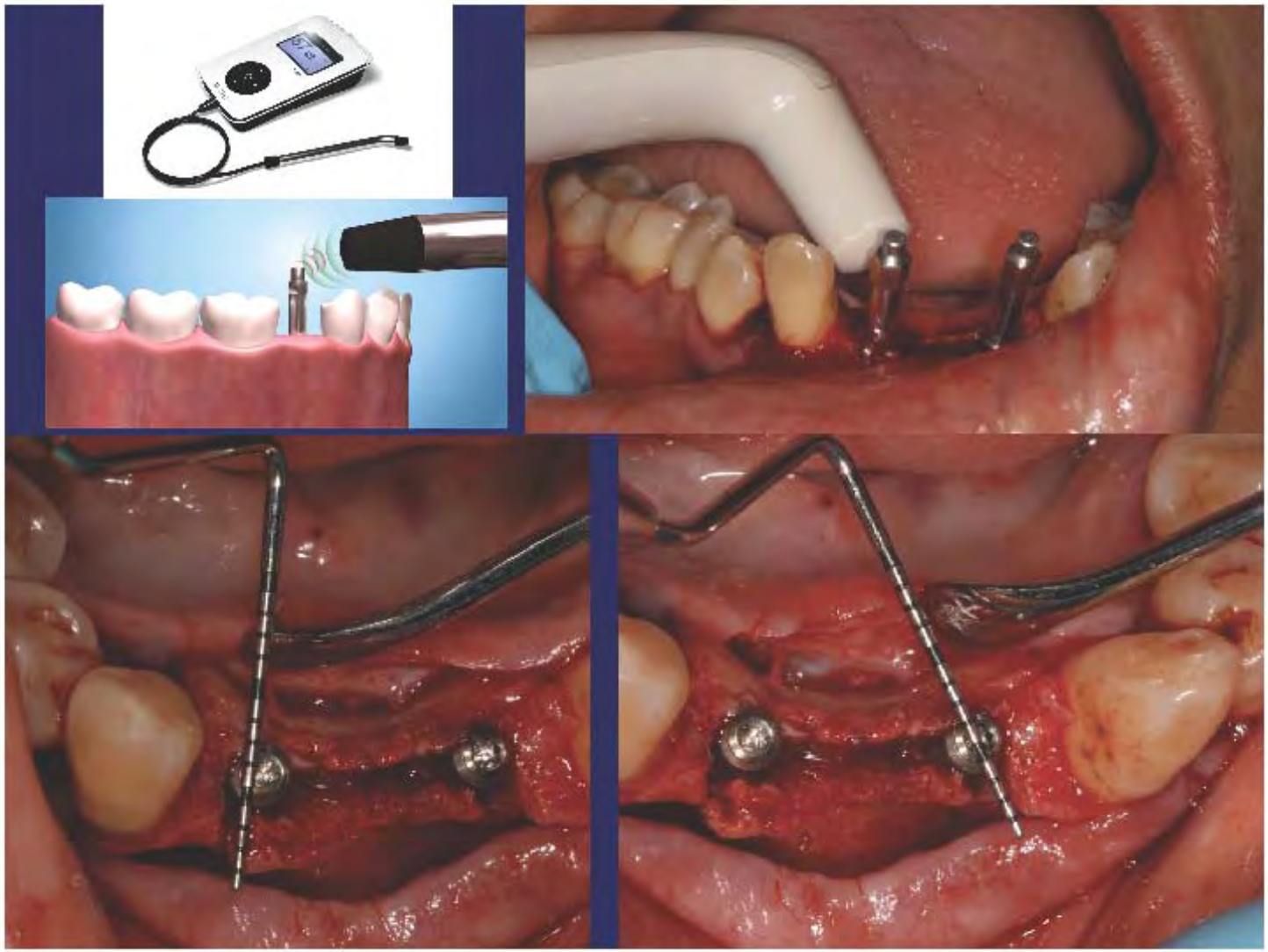


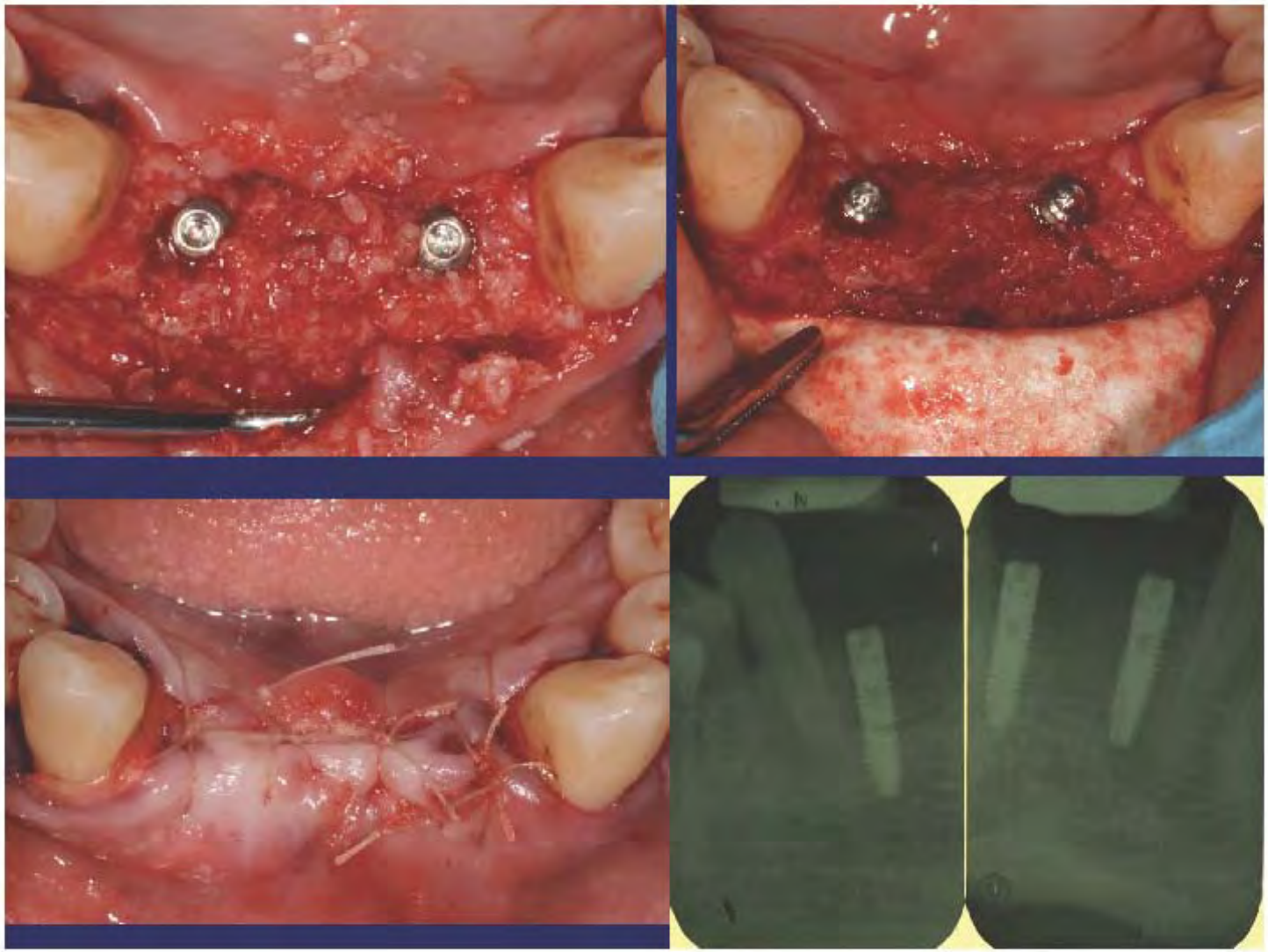
Lower Anterior Segmental Ridge-split Surgery





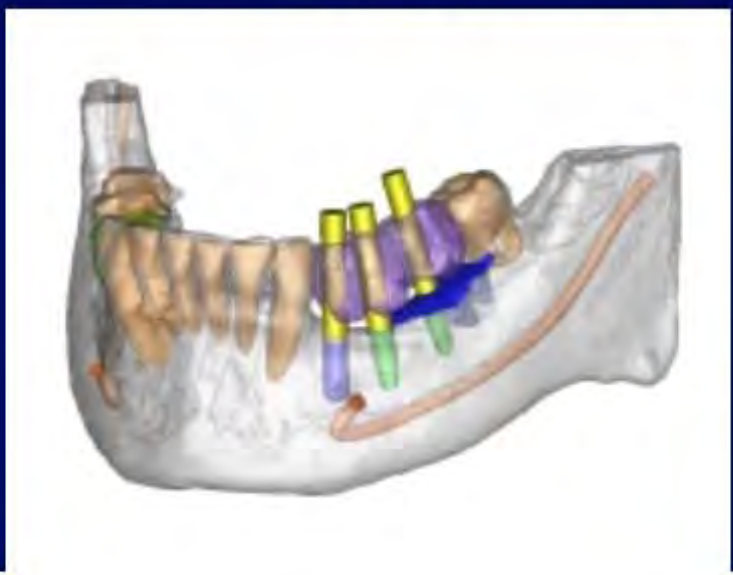


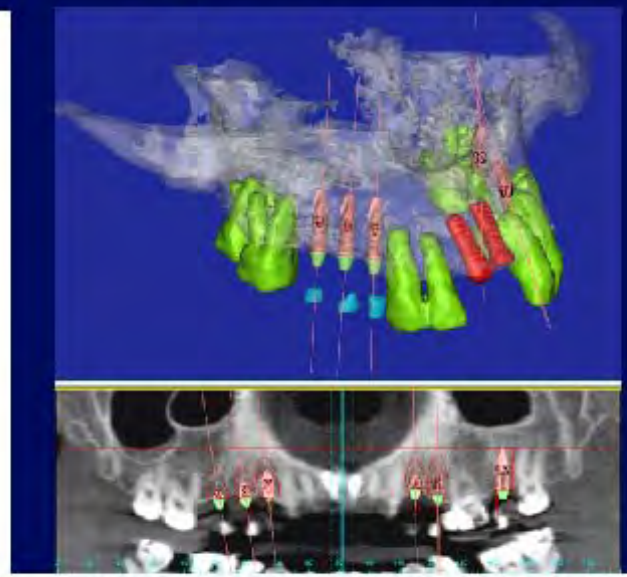




3D Virtual Implant Placement Software Programs

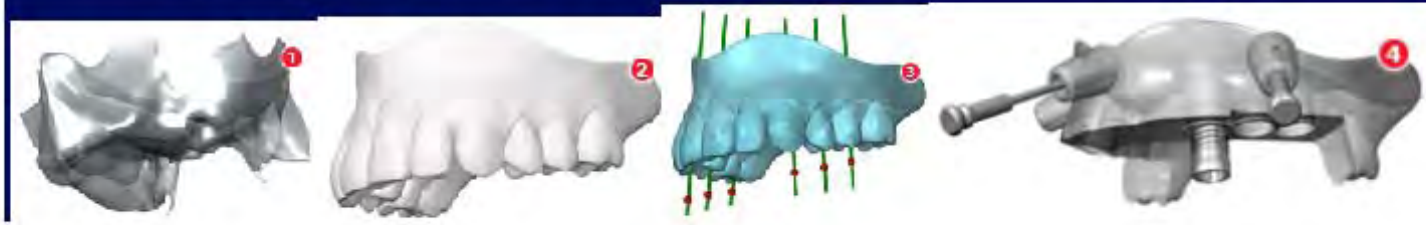
- As we know, there are 3D virtual implant placement software programs available that assist in the proper position of dental implants
- The "big" programs are - Nobelguide and Simplant





How do these programs work?

- A CBCT is taken with a radiographic stent in place
- A virtual implant is chosen from a range of implant options varying in lengths and diameters.
- The virtual implant is placed in the optimal position according to critical information defined by critical structures.
- Based on the image and implant planning data, the software generates a virtual surgical guide on the jaw with the planned implant position
- The surgical guide is then produced by stereolithography.



Custom-made Stereolithographic Surgical Guides

Bone-supported SurgiGuide

- Dental drill guides are placed on the jawbone
- Suitable for partially or fully edentulous cases when increased visibility is needed
- Sufficient bone surface support is essential for secure, effective drill guide positioning

Tooth-supported SurgiGuide

- Dental drill guides are placed directly onto the teeth
- Recommended for single tooth and partially edentulous cases when minimally invasive surgery is required
- A plaster cast or an optical scan of the cast is necessary

Mucosa-supported SurgiGuide

- Dental drill guides are positioned on the soft tissue
- Ideal for fully edentulous cases when minimally invasive surgery is preferred
- A radio-opaque scan prosthesis is required if the Single Scan Guidelines are to be followed.

Stereolithographic Surgical Guides

Combining the visualization of a virtual model of the jaw, with computer aided design software it is possible to plan implant placement and make constraining drill-guides using 3D manufacturing techniques.

When fitted to the jaw, the guides precisely constrain implant site preparation, allowing implants to be placed using a minimally invasive approach directly into pre-planned positions.

Dawood et al. Br Dent J. 2009; 207(1):23-8.

CBCT Guided Surgery

Stereolithographic surgical guides with occlusal record in place and secured with three 2 mm bone screws

Palatal bone screw

Tissue punches: drill speed 100 – 300 rpm

Starter drills - perforate the cortical plate and create a 2 mm pilot; drill speed 1200 – 1500 rpm

2 mm twist drills and drill positioning handles; drill speed 1200 – 1500 rpm

3 mm twist drills and drill positioning handles; drill speed 1200 – 1500 rpm

The implants were placed through the surgical guide; drill speed 15 – 20 rpm

Final seating of the implants were accomplished using a hand ratchet

All six implants were placed

The implant mounts and surgical guide were removed. RFA performed to confirm initial stability

Conical abutments were connected to implants and tightened to 20 Ncm

Quick bridge titanium cylinders were tightened to the abutments and quick bridge caps were snapped onto the titanium cylinders

The prosthesis was filled with acrylic resin

Try in of provisional restoration

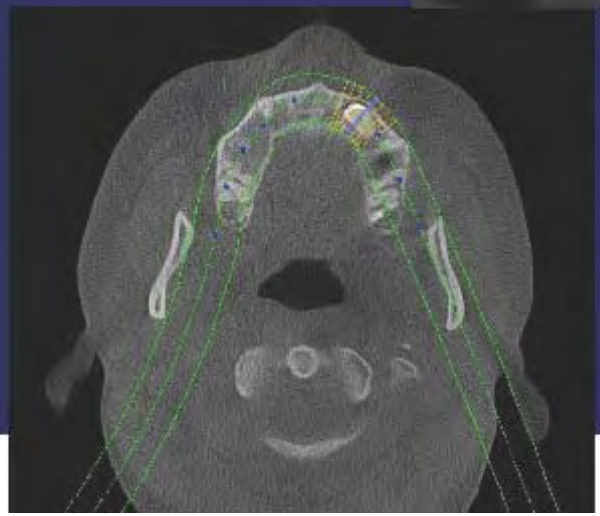
Patient was brought to C.O.

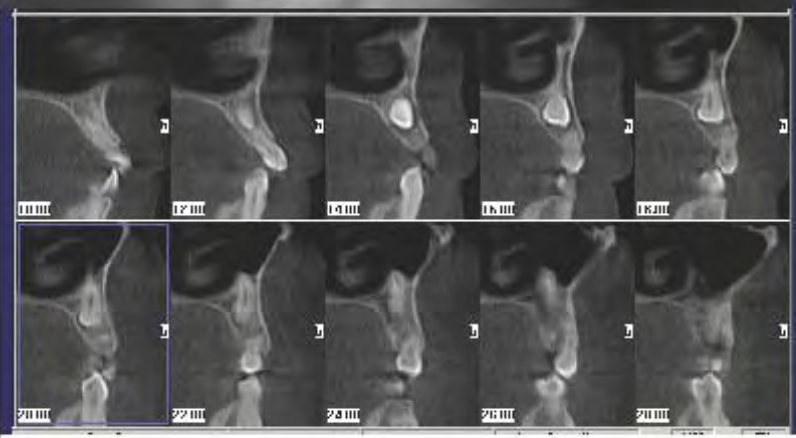
Removed the prosthesis when acrylic resin has set

The quick bridge caps were incorporated into the restoration

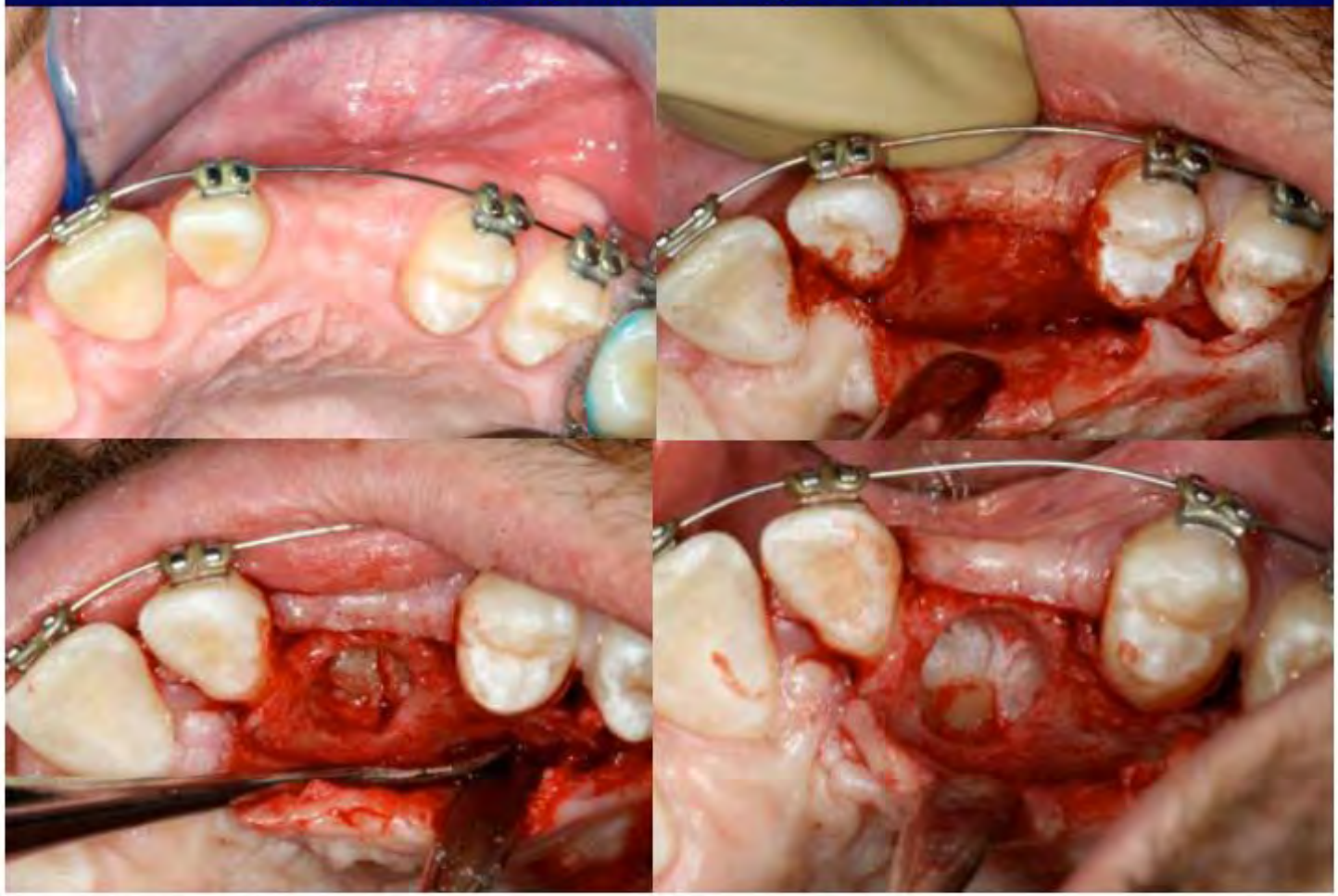
The prosthesis was snapped into the position over the titanium cylinders

Orthodontics – Tooth Position





Surgical Exposure of Impacted Canine



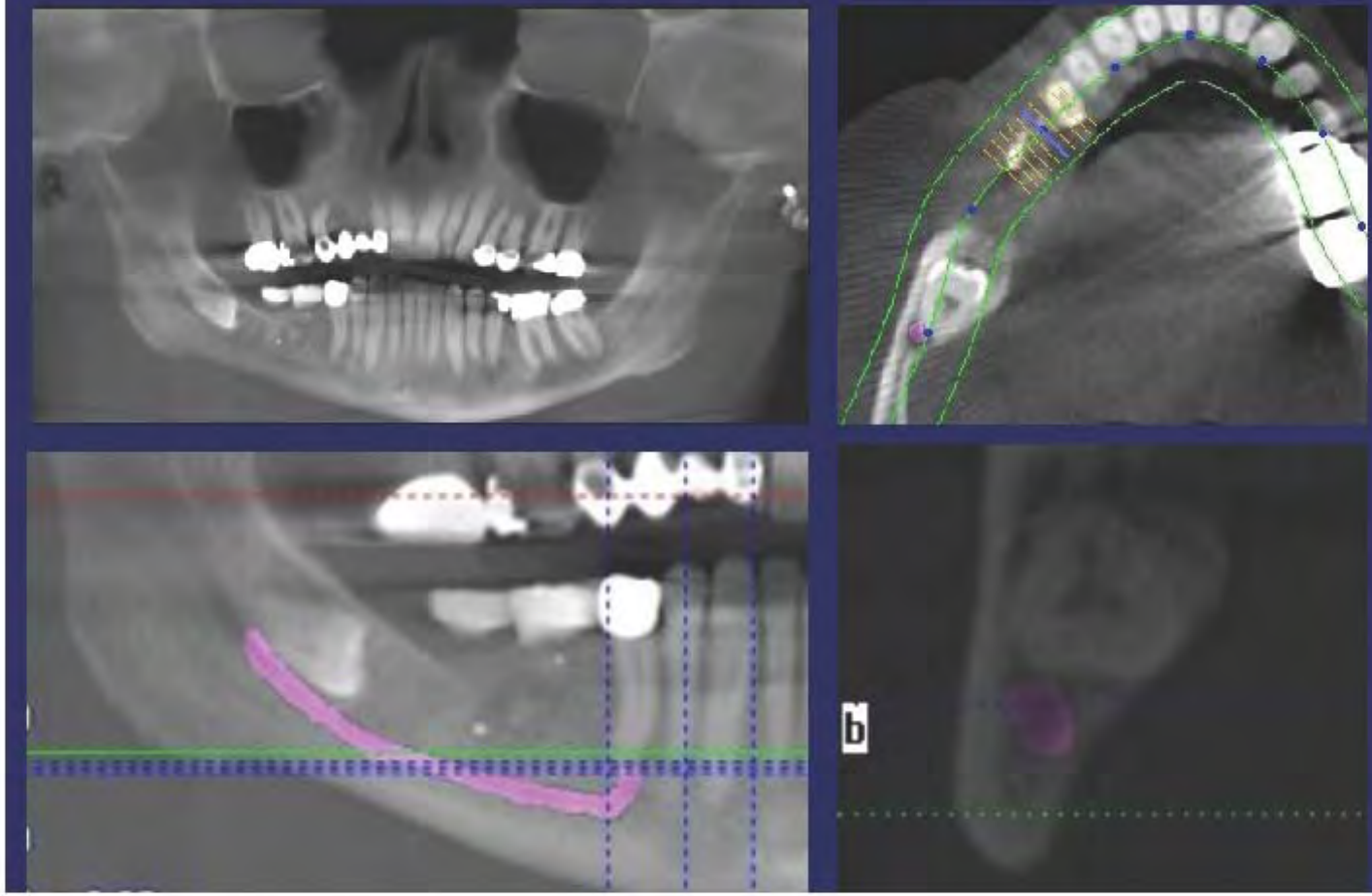

1 week post-op

Surgical Exposure of Impacted Canine

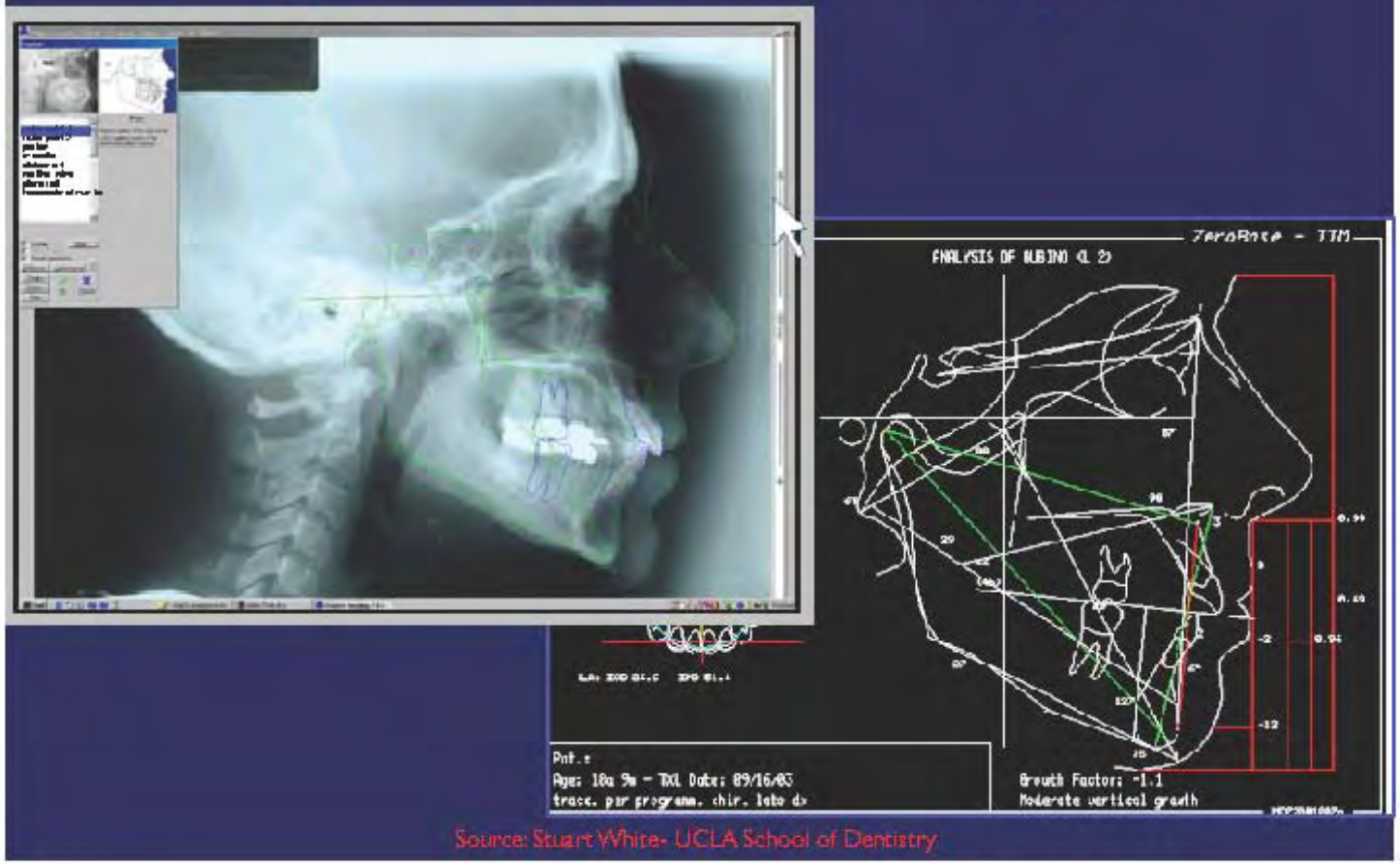
11 months post-op

17 months post-op

Location of Inferior Alveolar Nerve



Cephalometric Analysis

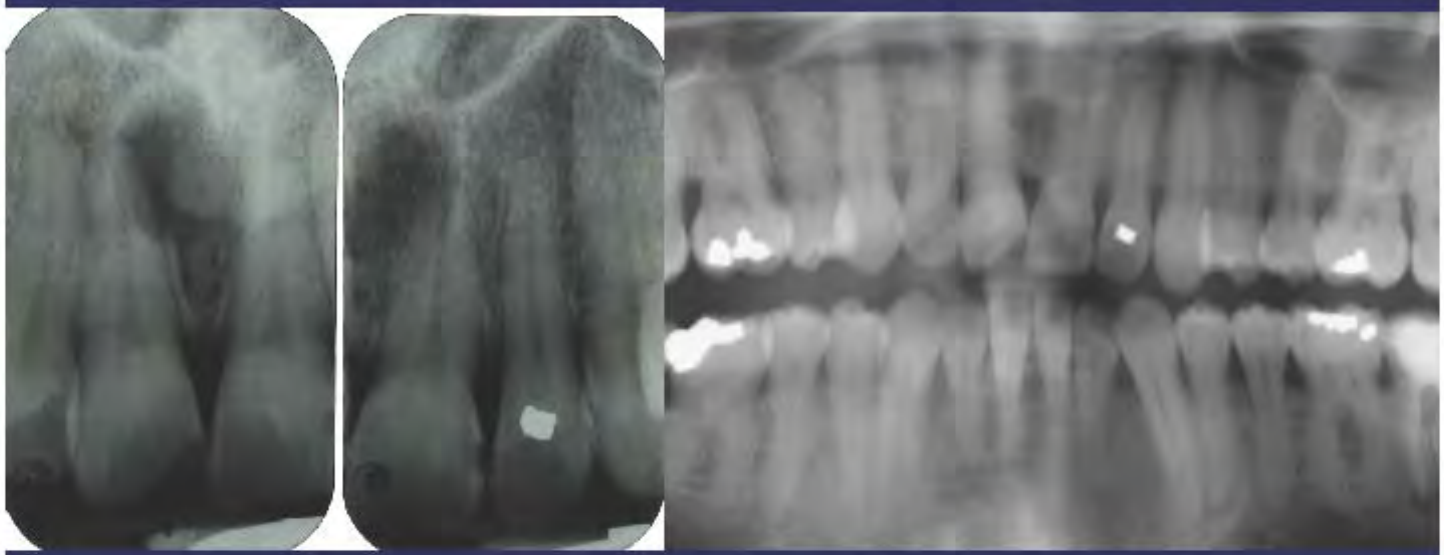


Source: Stuart White- UCLA School of Dentistry

Cephalometric Analysis

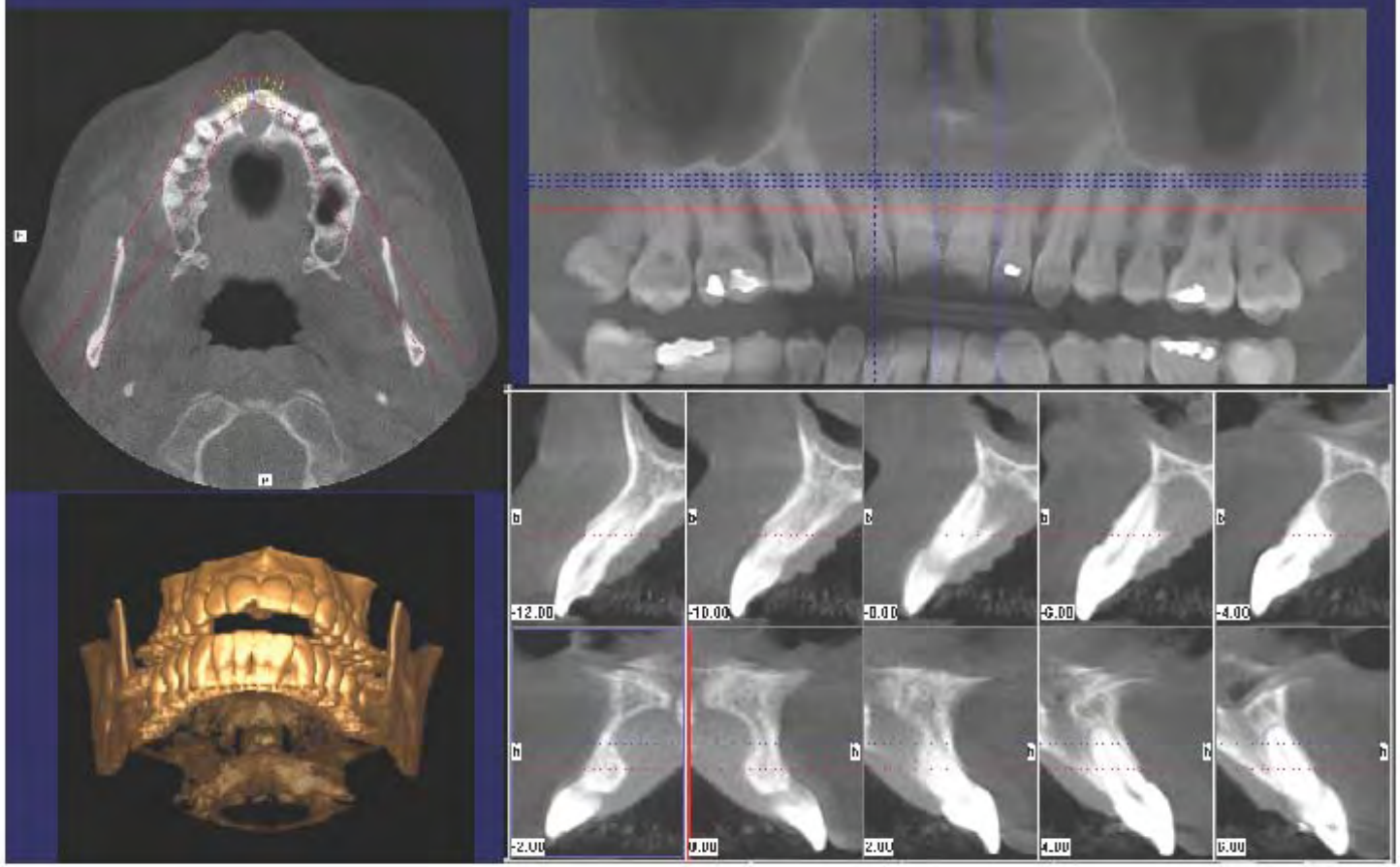
Source: Stuart White- UCLA School of Dentistry

Maxillofacial Pathology



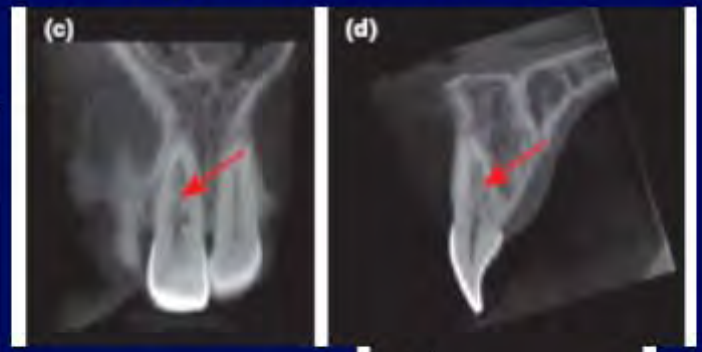
PA and Pano Images

CBCT Images - NPDC



Detection of Root Resorption Lesions

Typical PA films

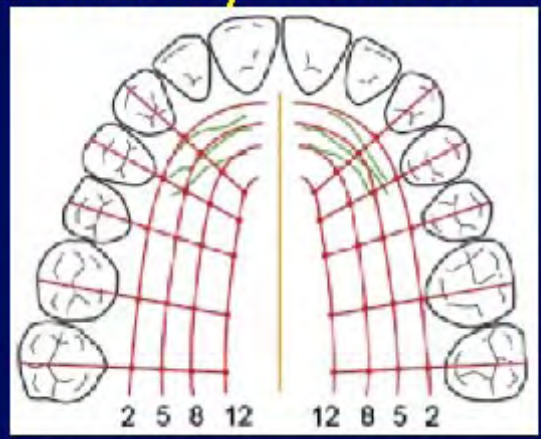


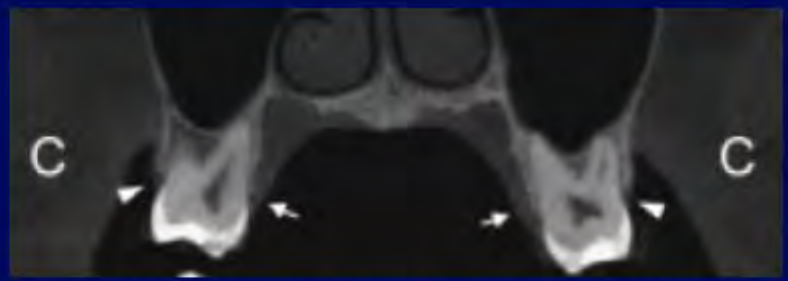
Typical CBCT

(a–b) Typical PA radiographs. A cloudy radiolucency (yellow arrow) is present in the mid-third of the root. (c–e) A typical series of CBCT reconstructed (coronal, sagittal and axial) views of the same tooth to assess diagnostic accuracy of cone beam computed tomography. An external cervical root resorption lesion (red arrow) can clearly be seen, note the severity of the lesion.

Patel et al. Int Endod J. 2009;42(9):831-8.

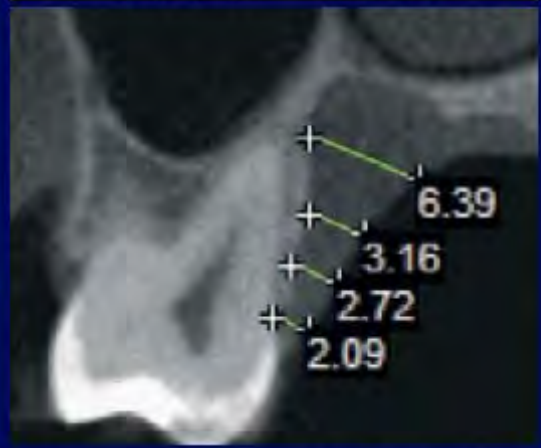
Measurement of Palatal Masticatory Mucosa





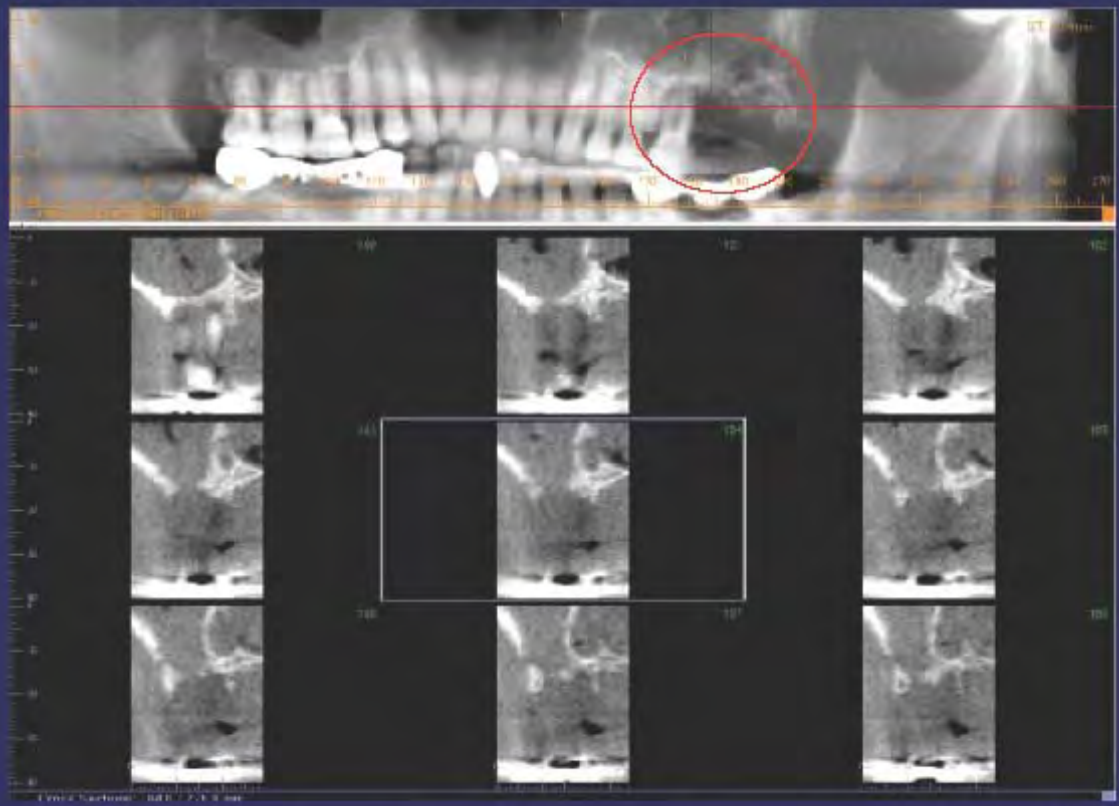
CBCT scan showing soft and hard tissues of both facial and palatal aspects of the first maxillary molars. C, cheeks; arrowheads, facial gingiva; arrows, palatal masticaticatory mucosa.

Barriviera et al. J Clin Periodontol 2009; 36: 564–568



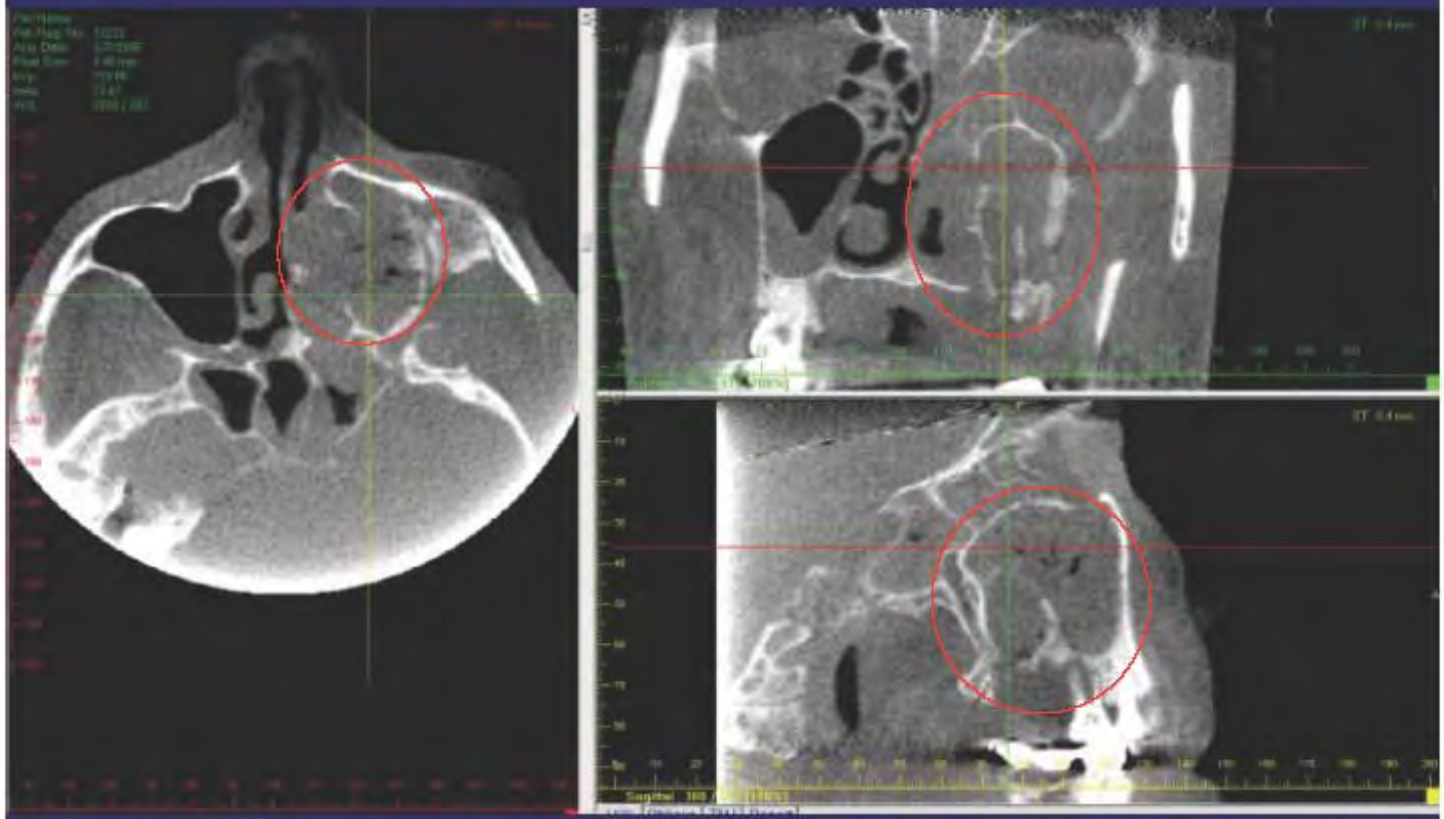
Precise measurements obtained with the i-CAT software

Bisphosphonate Related Osteonecrosis of the Jaw



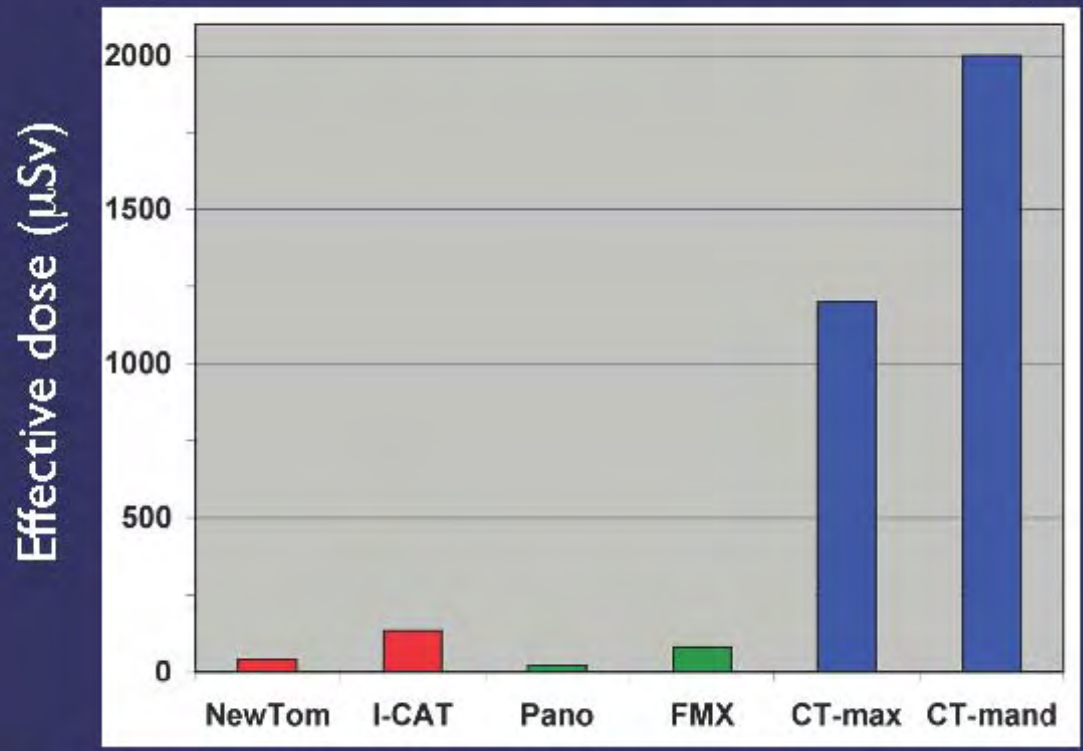
Preoperative CBCT reformatted panoramic view (**A**) and cross-sections perpendicular to the axis (**B**) showing an extensive radiolucent region of bone destruction with bony sequestra encompassing the maxillary left first molar and extending to the tuberosity on that side, as well as extensive thickening of the mucosa and possible erosion of the sinus floor and medial wall. (Kumar et al. J Can Dent Assoc 2006; 72(1):75–80)

Bisphosphonate Related Osteonecrosis of the Jaw



Preoperative CBCT crosssectional slices (axial **[A]**, coronal **[B]** and sagittal **[C]**) through the left sinus showing extensive inflammation of the maxillary sinus and possible erosion of the medial wall. (Kumer et al. J Can Dent Assoc 2006; 72(1):75–80)

Comparative Dosimetry



NewTom: 30 µSv
Digital Panoramic: 4.7 – 14.9 µSv
Daily background: 8 µSv

i-CAT 20 second scan: 68 µSv;
FMX: 150 µSv

Panoramic (Average): 10-15 µSv
Medical CT: 1200-2000 µSv

Source: Stuart White- UCLA School of Dentistry

Benefits and Limitations

Benefits

- 3D dataset
- Real-size data
- Potential for generating all 2D images (e.g.orthopantomogram, lateralcephalogram, TMJ)
- High resolution (e.g. bone trabeculae, Periodontal ligament (PDL), root formation)
- Lower radiation dose than MSCT
- Less disturbance from metal artifacts
- Reduced costs compared with MSCT
- Easy accessibility and handling
- In-office imaging
- Digital Imaging and Communications in Medicine (DICOM) compatible
- User-friendly post-processing and viewing software

Limitations

- low contrast range (dependent on the type of X-ray detector)
- Limited detector size causes limited field of view and limited scanned volume
- Limited inner soft tissue information
- Increased noise from scatter radiation and concomitant loss of contrast resolution
- Movement artefacts affecting the whole data set (stay still for 10-40 sec.)
- Can not be used for estimation of Hounsfield units (HU)

De Vos et al. Int J Oral Maxillofac Surg. 2009; 38: 609–625

Future Predictions for CBCT Imaging

Question #1: Will intraoral and panoramic imaging disappear or be replaced by CBCT?

Prediction #1: Although we may use fewer intraoral images, both bitewing and periapical,and even with advances in panoramic techniques and software that can replace some intraoral images, we still will need the higher resolution capability of film or digital intraoral images for high-risk "caries patients" to see the earliest lesions. Cone beam imaging will not replace intraoral or panoramic.

Miles. Dental Clinics of North America 52:917–928, 2008.

Question #2: Will tomography or panoramic imaging technique be replaced by CBCT?

Prediction #2: CBCT will replace conventional tomography as the "standard of care," and should now be used in place of panoramic imaging to assess any implant site.

Question #3: Will CBCT replace conventional CT as the "state-of-the-art" or the "standard of care" for presurgical implant site evaluation?

Prediction #3: CBCT will replace conventional CT as the standard of care for implant assessment.

Question #4: Will the "cephalometric" image reconstructed from a CBCT data volume replace the conventional cephalometric image for cephalometric analysis?

Prediction #4: CBCT will replace conventional cephalometric x-ray technique as the standard of care within 7 to 10 years after the "science" has been completed.

Question #5: Will CBCT imaging replace panoramic imaging for third molar extraction?

Prediction #5: CBCT will replace conventional panoramic images as the standard of care only for difficult third molar extraction cases.


60th Anniversary
Periodontology
THANK YOU FOR YOUR ATTENTION