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Review Article

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2D Versus 3D In Endodontic Diagnosis and Therapy: Case Series and Literature Review

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Abstract

Aim: Radiographic assessment is central to endodontic diagnosis and treatment planning. This investigation evaluated the contribution of Two-Dimensional (2D) and Three-Dimensional (3D) imaging, individually and in combination, to the recognition and management of endodontic problems.

Materials and Methods: Clinical and radiographic examples obtained from endodontic patients were reviewed using several 2D modalities, including periapical radiography, Panoramic Radiography (OPG), RadioVisioGraphy (RVG), digital subtraction radiography, occlusal radiography and bitewing radiography. Three-dimensional modalities included Computed Tomography (CT), Magnetic Resonance Imaging (MRI) and Cone-Beam Computed Tomography (CBCT).

Results: In the cases evaluated, 3D imaging provided additional diagnostic information and improved visualization of several endodontic conditions when compared with 2D imaging. Digital 2D techniques also offered practical and diagnostic advantages over conventional film-based methods.

Conclusion: Conventional 2D radiography remains useful for routine endodontic assessment, particularly when disease is radiographically evident. When 2D findings are inconclusive or the anatomy is complex, 3D imaging may provide clinically relevant information that can modify diagnosis or treatment planning and support favorable treatment outcomes.

Keywords: Conventional Radiography; Digital Radiography; Two-Dimensional Imaging; Three-Dimensional Imaging; Endodontics

Introduction

Radiographic examination is an essential component of dental diagnosis and has particular importance in endodontics. It supplements the clinical examination by providing information about the tooth, root canal system, periradicular tissues and adjacent anatomical structures. Nevertheless, radiographic findings should be interpreted together with the patient's history and clinical findings rather than being regarded as an isolated diagnostic test, because both normal anatomy and disease may produce misleading radiographic appearances [1,2].

Successful endodontic treatment requires correct identification of the tooth requiring treatment and an adequate understanding of root and canal morphology. Radiographs therefore contribute to canal localization and to the procedures of cleaning, shaping, obturation and subsequent evaluation of treatment [1-10].

Imaging is used at several stages of endodontic care. It may demonstrate changes in dental and periradicular hard tissues, assist in evaluating the extent of disease and provide a basis for follow-up. However, conventional 2D images compress three-dimensional anatomy into a flat representation and are affected by superimposition. They cannot reliably distinguish among a chronic apical abscess, granuloma and cyst; histopathological examination is required for such differentiation. Anatomical radiolucencies, including the maxillary sinus, incisive foramen and mental foramen, may also simulate periapical disease. In addition, the radiographic size of a lesion may not correspond precisely to its actual dimensions [2-10].

Digital radiography and 3D techniques have expanded the information available to the clinician. RVG and digital subtraction radiography permit digital acquisition and image processing, whereas CBCT provides volumetric visualization of dentoalveolar structures. The purpose of the present investigation was to illustrate endodontic cases examined with 2D and 3D techniques and to consider how the additional information provided by advanced imaging may influence diagnosis, treatment and follow-up.

Materials and Methods

A series of clinical and radiographic endodontic cases was evaluated using the imaging techniques summarized in Table 1. Two-dimensional methods included periapical, panoramic, RVG, digital subtraction, occlusal and bitewing radiography. Three-dimensional assessment included CT, MRI and CBCT. The images were compared with respect to their ability to demonstrate clinically relevant endodontic anatomy and pathology and to assist treatment planning.

2D Radiographic Techniques	**3D Imaging Techniques**
Periapical radiography	Computed Tomography (CT/CAT)
Panoramic Radiography (OPG)	Magnetic Resonance Imaging (MRI)
RadioVisioGraphy (RVG - digital)	Cone-Beam Computed Tomography (CBCT)
Digital subtraction radiography	
Occlusal radiography	
Bitewing radiography	

Table 1: Schematic representation of the 2D and 3D imaging techniques discussed in this manuscript.

Review of the Literature

Two-Dimensional Radiography

Traditional and digital 2D radiographs remain the most frequently used imaging methods in dental practice. Their main limitation is the projection of complex three-dimensional structures onto a two-dimensional image. Consequently, unusual canal anatomy, buccolingual relationships and the true dimensions of periradicular lesions may not always be represented accurately [1,2,11].

Periapical Radiography

Periapical radiography provides a detailed image of an individual tooth together with its root, periodontal space and adjacent alveolar bone. In endodontics it can assist in assessing the number, position, form and direction of roots and canals; estimating working length; detecting procedural complications such as perforation, ledge formation, transportation and separated instruments; checking master-cone position; evaluating obturation; and monitoring post-treatment changes. It is also useful during endodontic surgery for localization of root apices, foreign material and residual filling material [1,2,11,12].

Interpretation must take into account the limitations of projection radiography. Lesions confined to cancellous bone may be difficult to appreciate and the absence of an obvious radiographic change does not by itself exclude disease. Accurate positioning is therefore important. Parallel or modified-parallel techniques and additional mesial or distal horizontal tube shifts may provide complementary information. Technique errors, anatomical restrictions and processing problems can distort the final image (Fig. 1-34) [1,2,5,8-20].

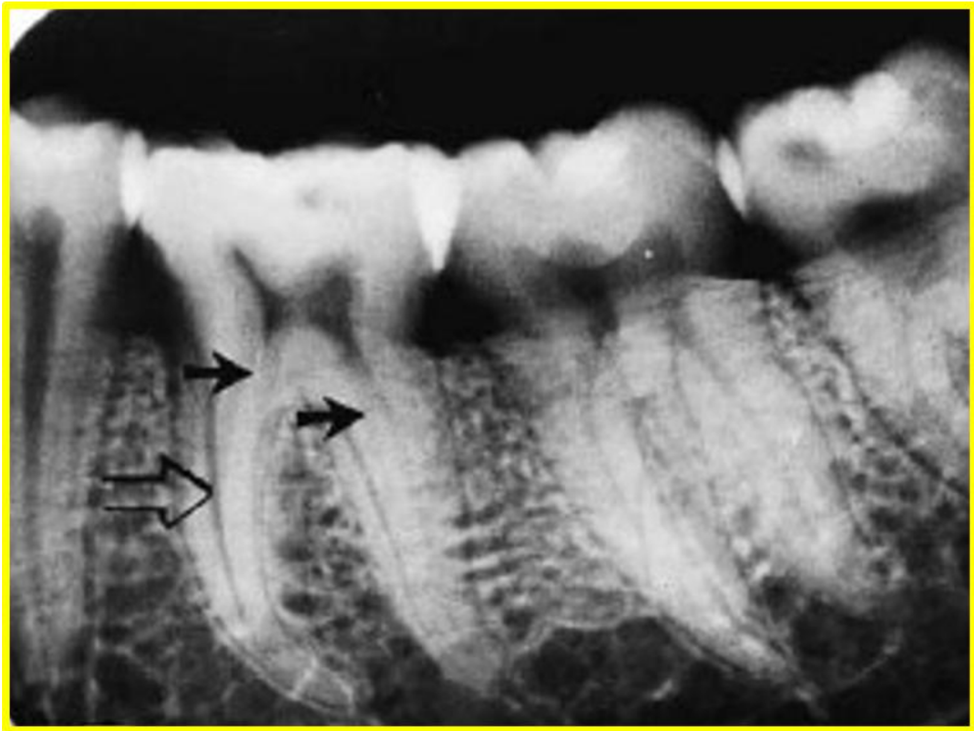


Figure 1: Open arrow indicates root outline. It emerges at gingiva, not into pulp chamber.

Figure 2: Total pulp calcification and external root resorption.

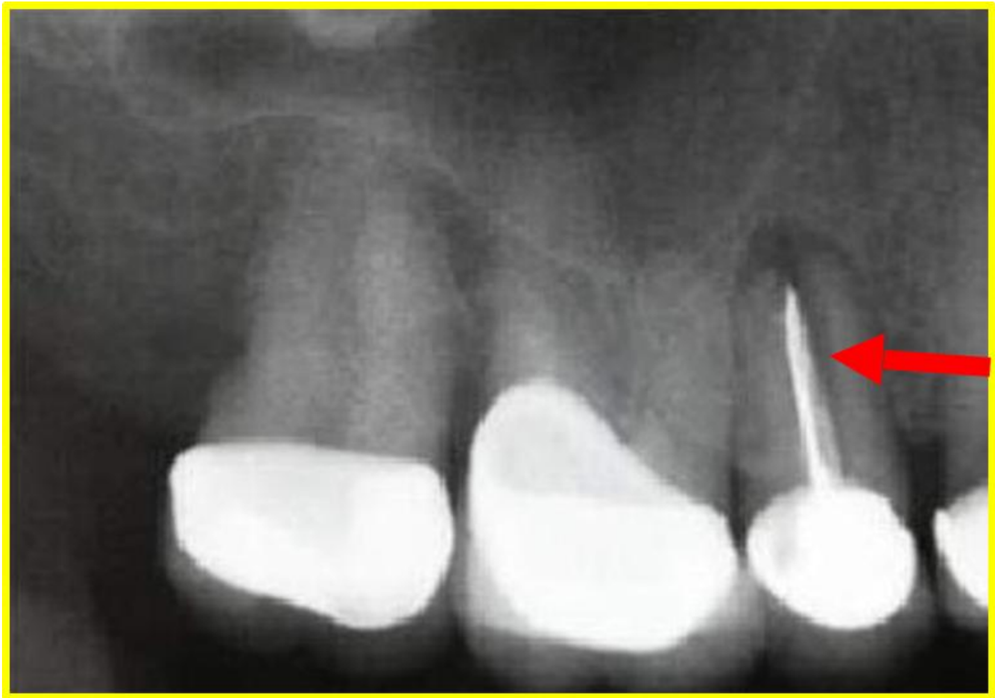


Figure 3: A space between filling and the canal wall (split tooth)

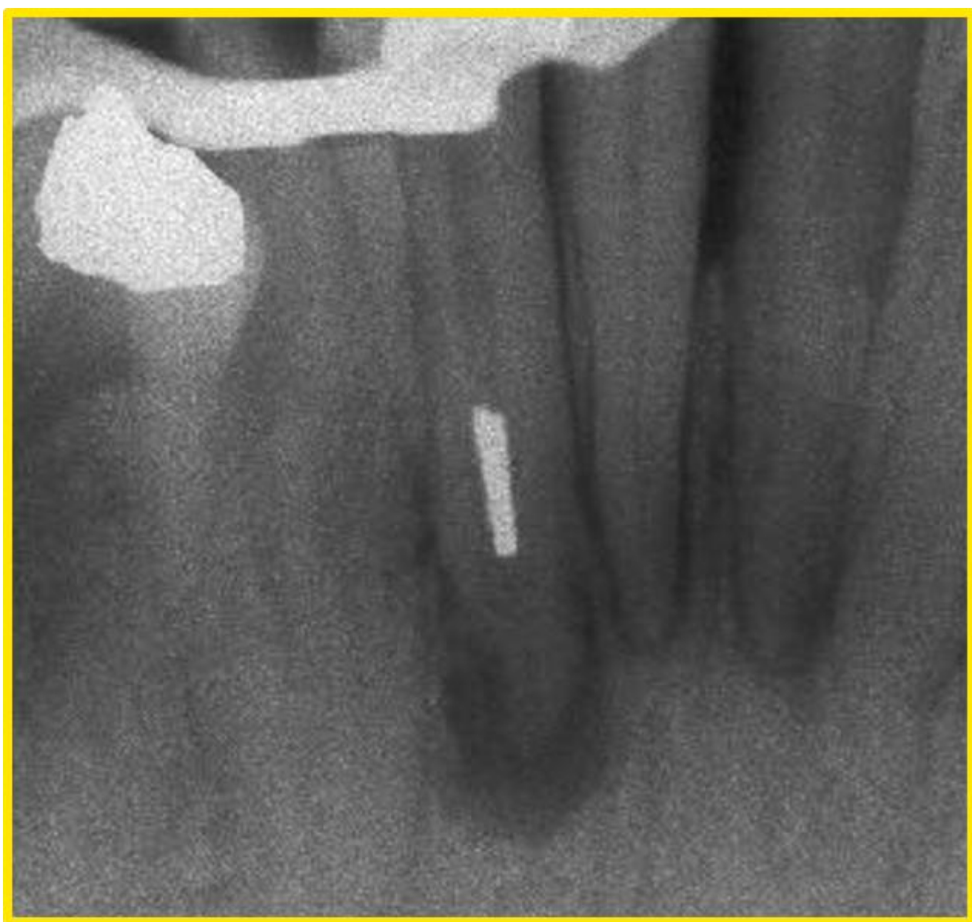


Figure 4: Separated bur.

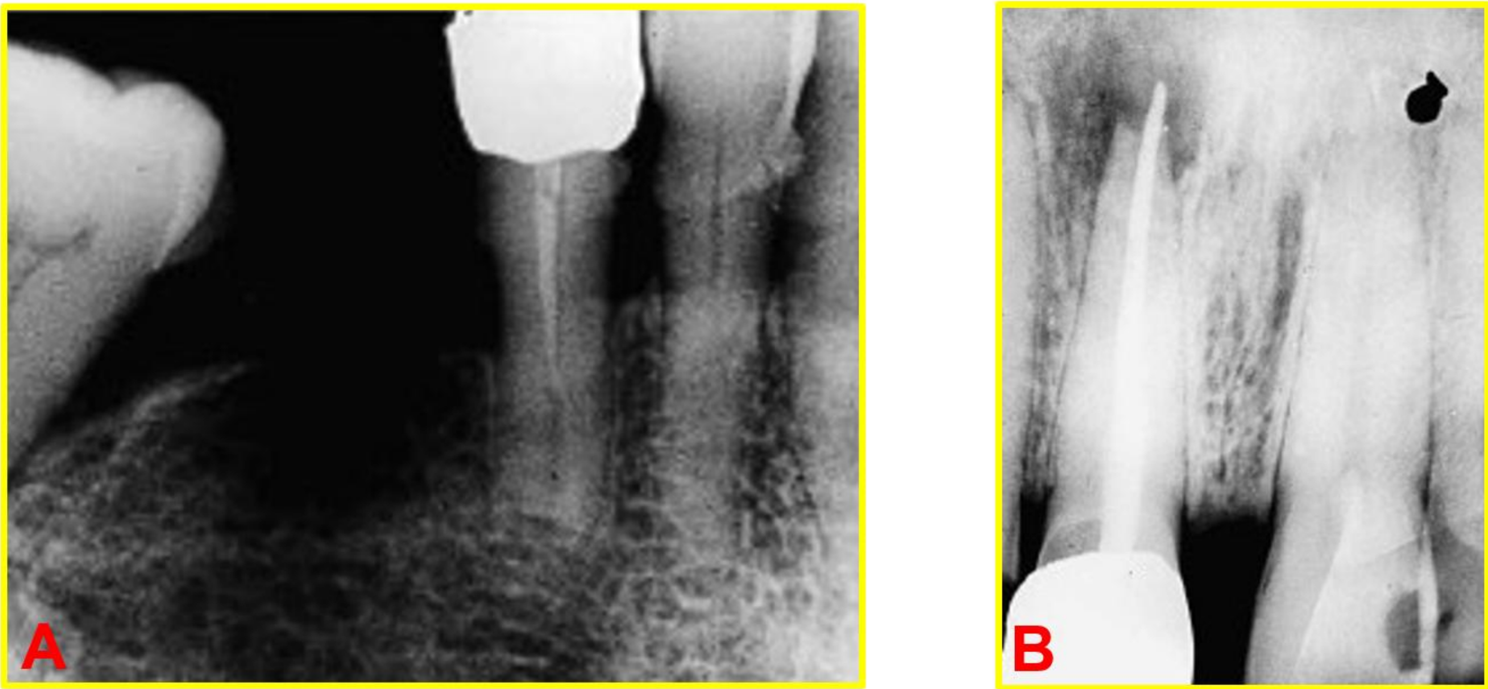


Figure 5: Under (A) and over extended filling (B).

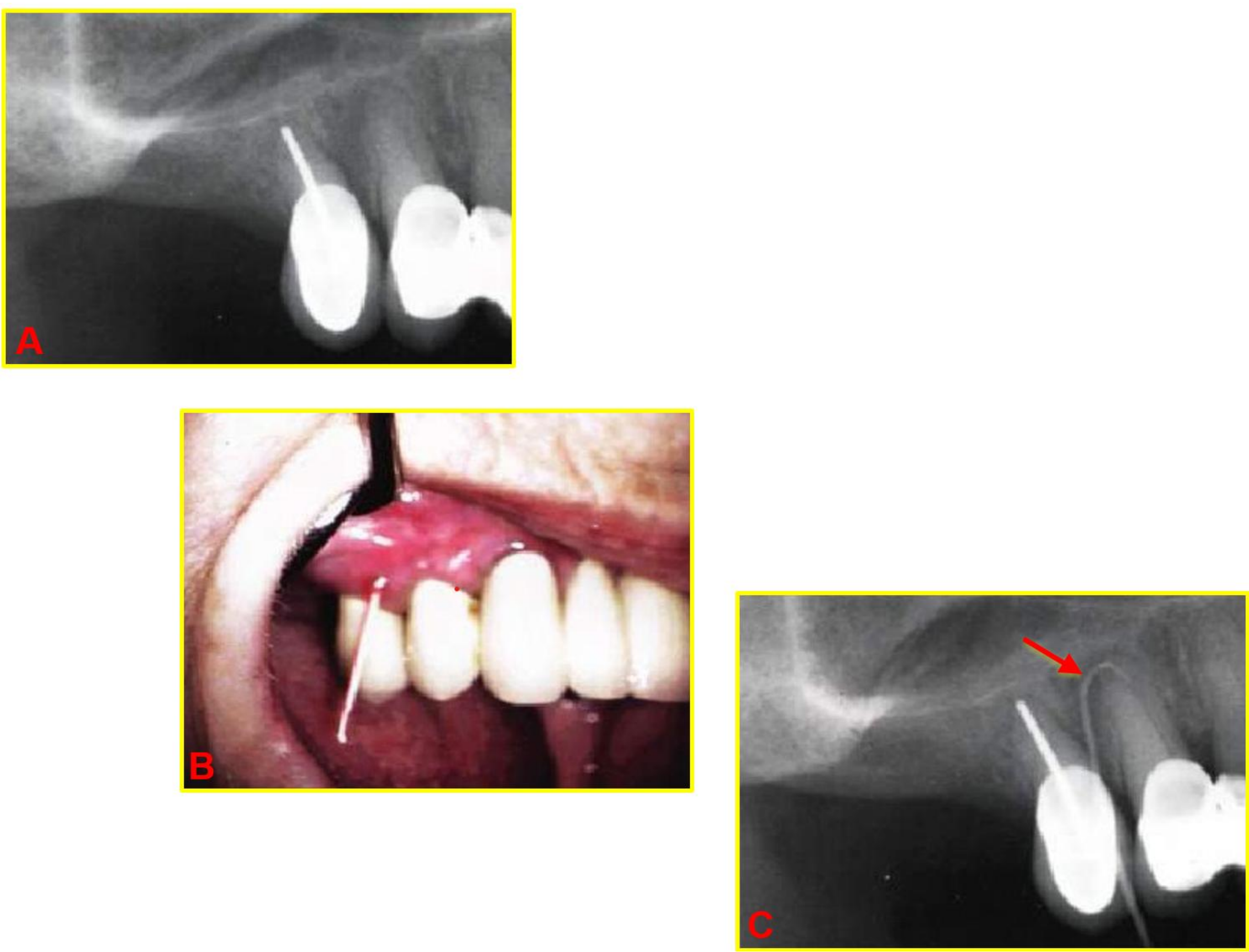


Figure 6: Sinus tract should be traced using gutta-percha (A - C).

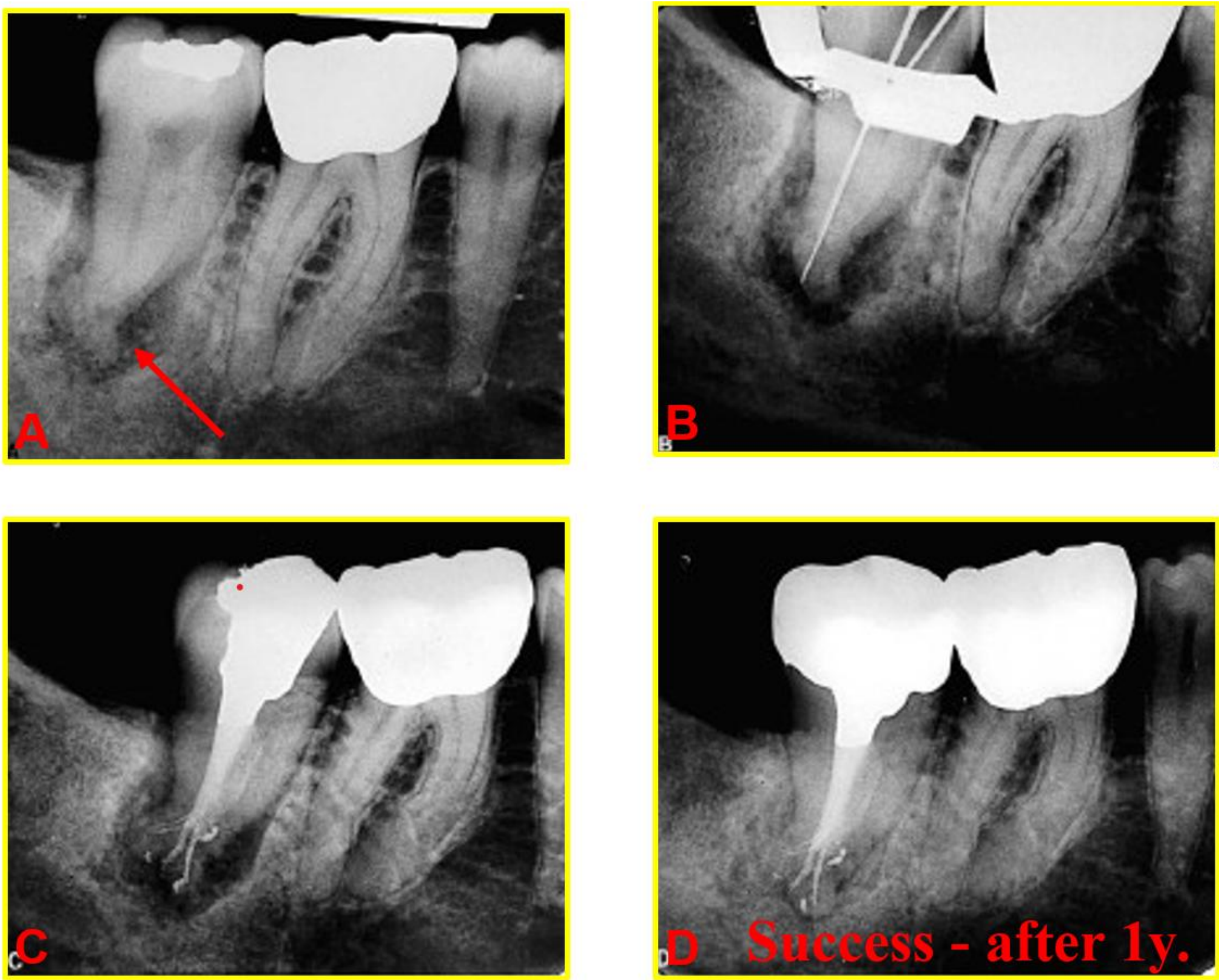


Figure 7: Treatment evaluation (A - D).

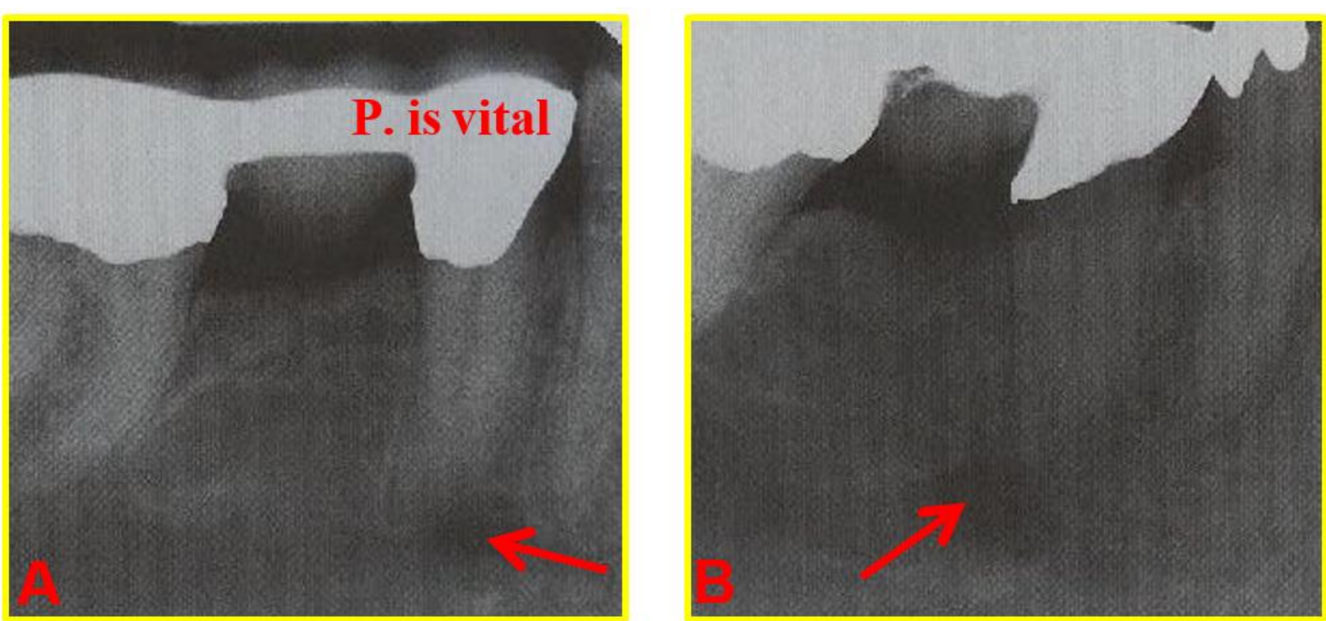


Figure 8: Mental foramen (change the angle - A,B).

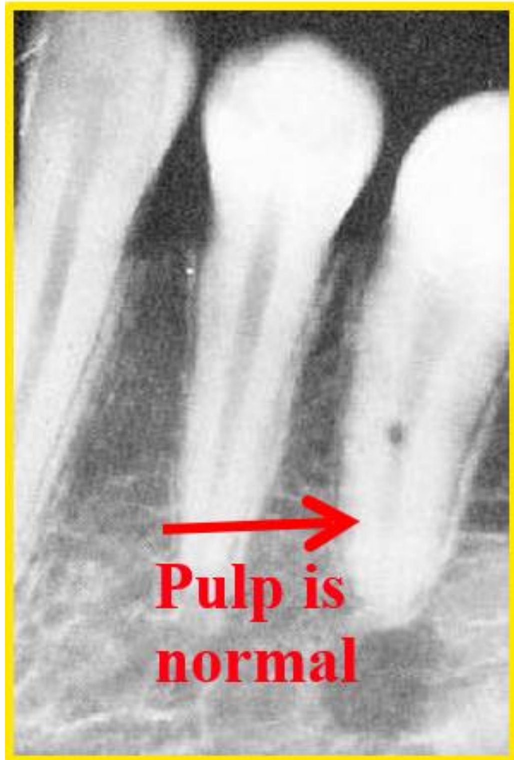


Figure 9: Mental foram and intact lamina dura.

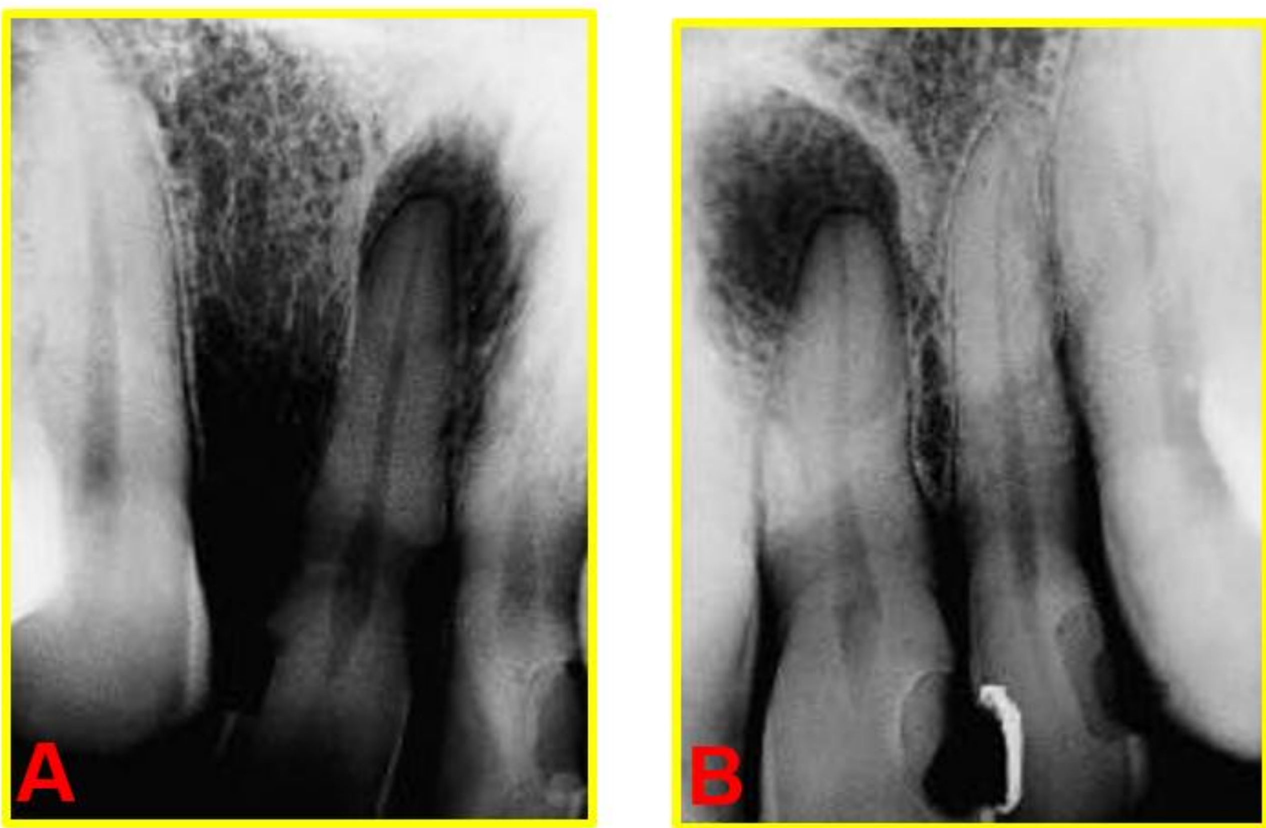


Figure 10: Nasopalatine foramen (change the angle - A,B).

Figure 11: Chronic apical periodontitis (Requires histopathologic examination).

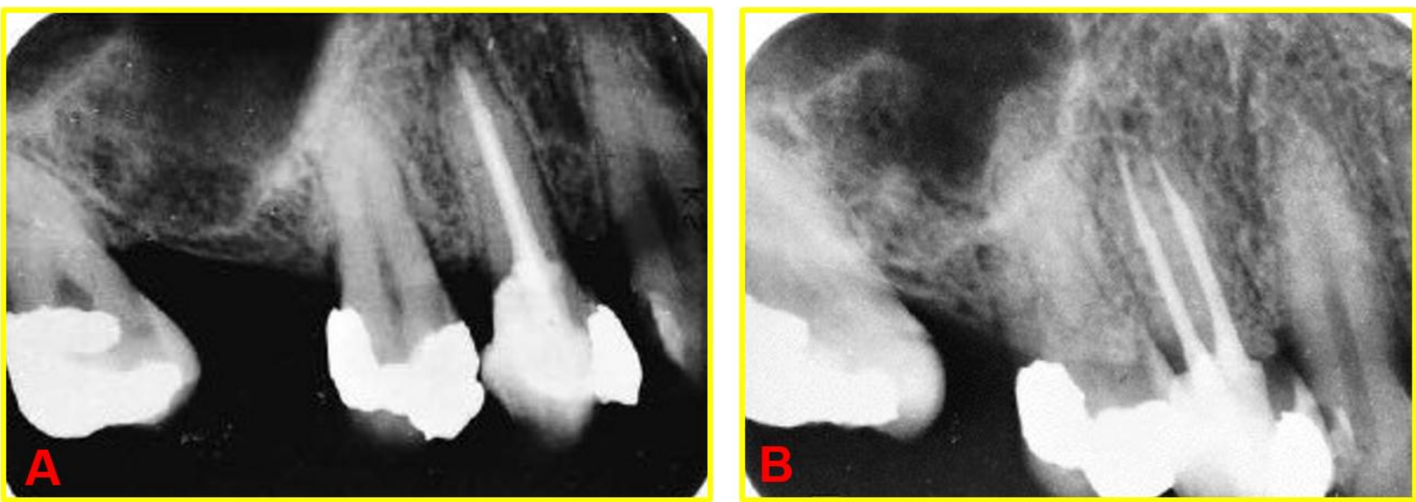


Figure 12: Straight (A) and mesial angle (B) projection.

Figure 13: Open arrow indicates root outline. It emerges at gingiva, not into pulp chamber.

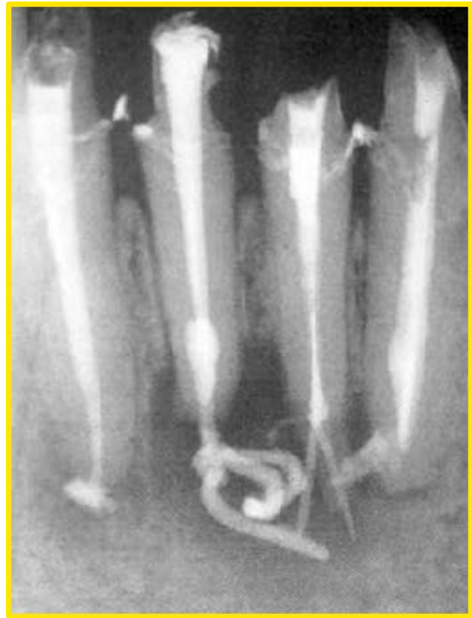


Figure 14: Spaghetti phenomenon.

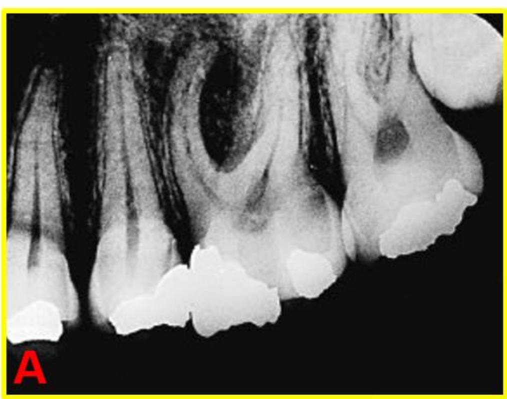


Fig. (A) Preoperative radiograph.

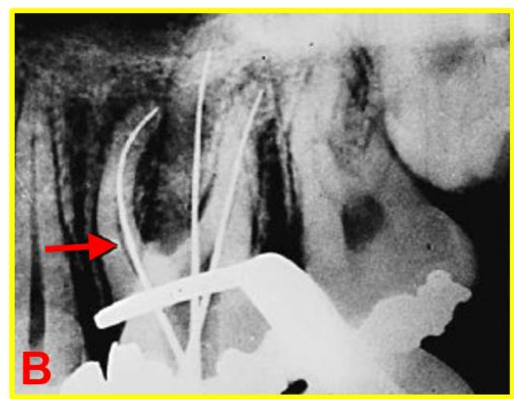


Fig. (B) Extra-dark line indicating 2 canals in the mesiobuccal root (red arrow).

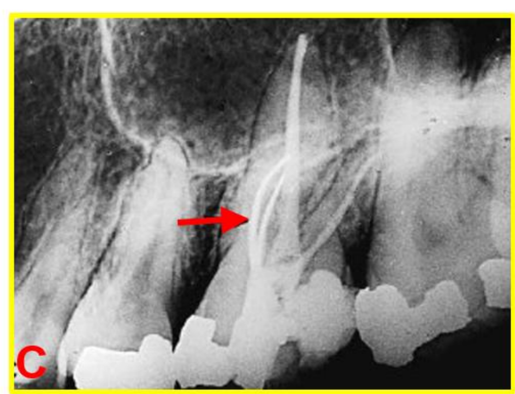


Fig. C Obturation.

Figure 15: (A) Preoperative radiograph; (B) Extra-dark line indicating 2 canals in the mesiobuccal root (red arrow); (C); Obturation.

Figure 16: Curved root (red arrow).

Figure 17: Fast break (splitting of root canal (red arrow).

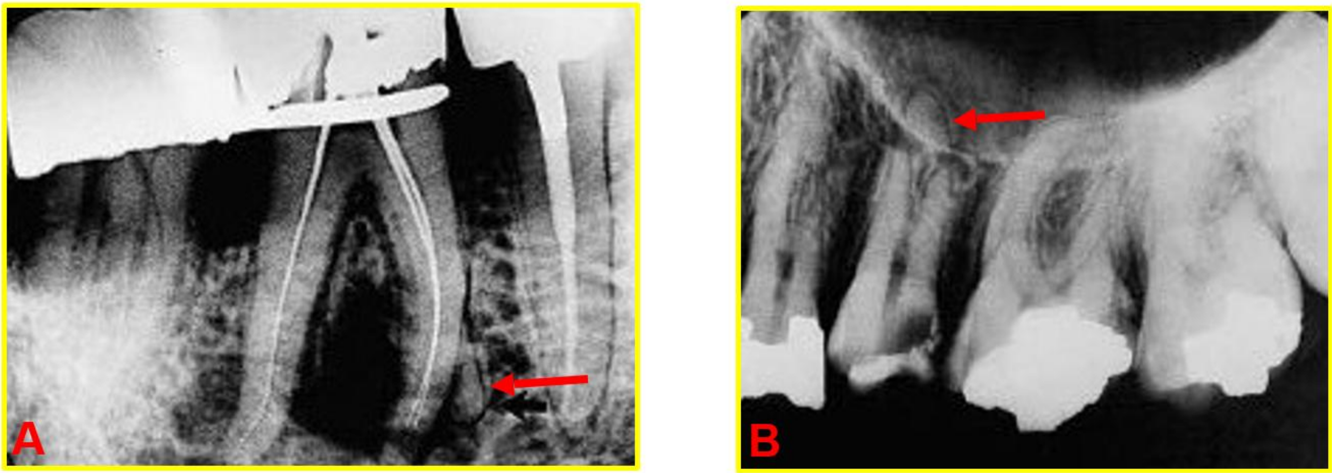


Figure 18: Additional root (red arrow) (A,B).

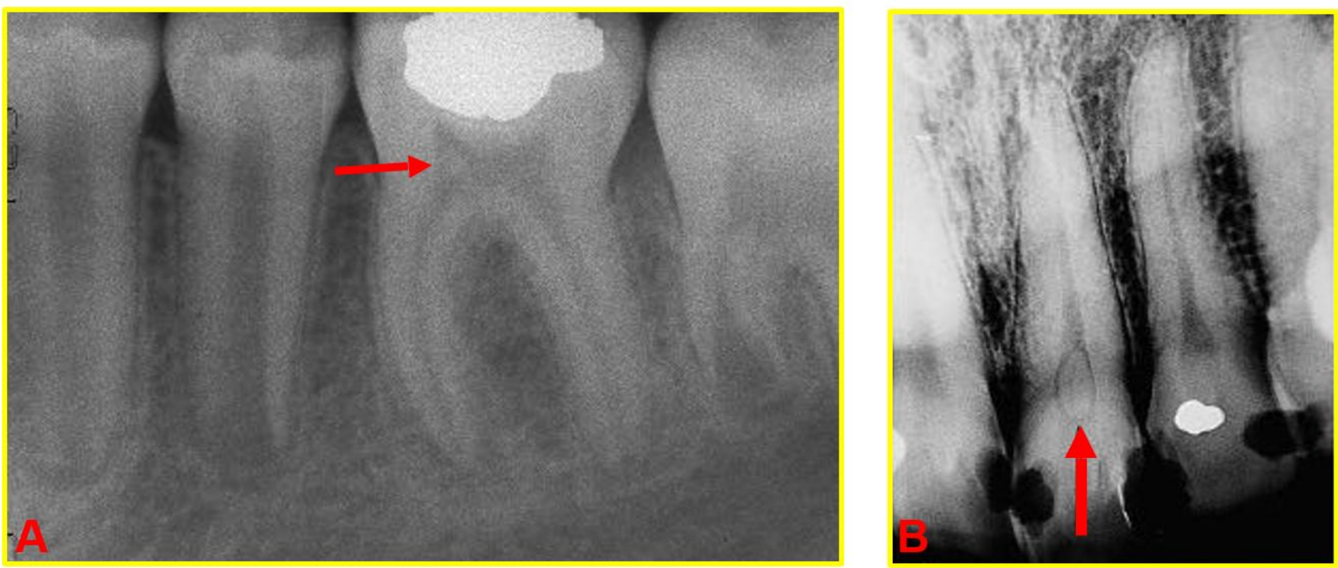


Figure 19: Pulp stone (A,B).

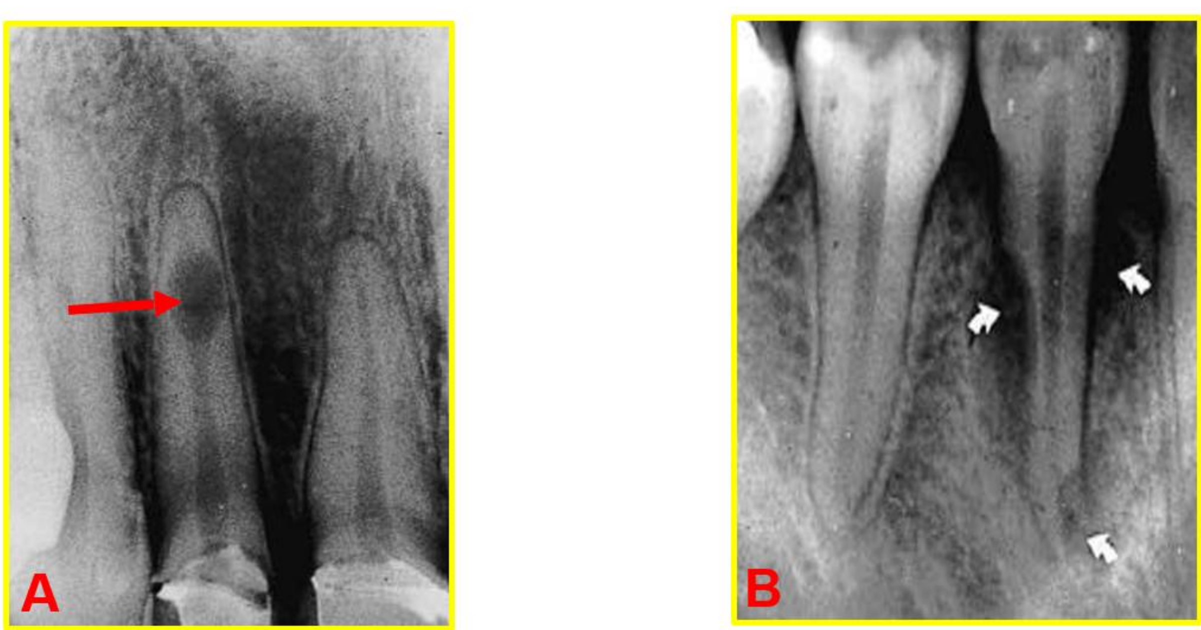


Figure 20: Root resorption (A: internal, B: external).

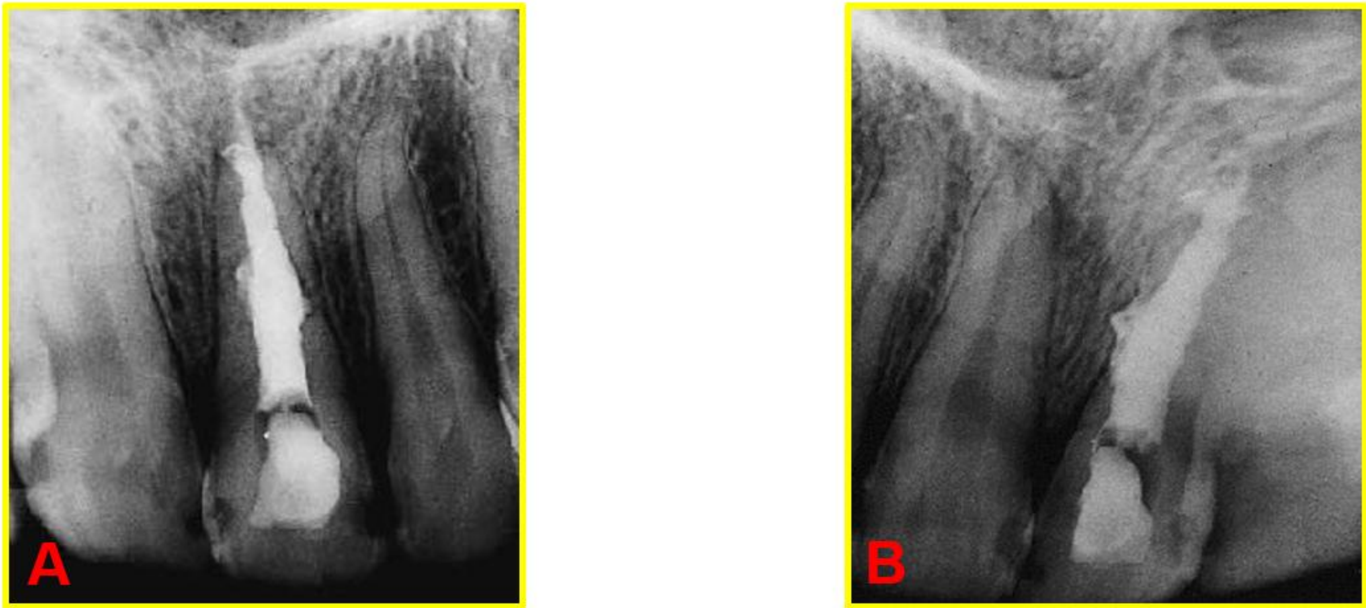


Figure 21: Internal root resorption (A: labio-lingaual projection, B: mesial projection) showing root perforation extended mesio-lingually.

Figure 22: Internal resorption, sharp smooth margins. Pulp shadow disappears (red arrow).

Figure 23: External resorption, ragged margin. Pulp shadow passes through lesion (red arrow).

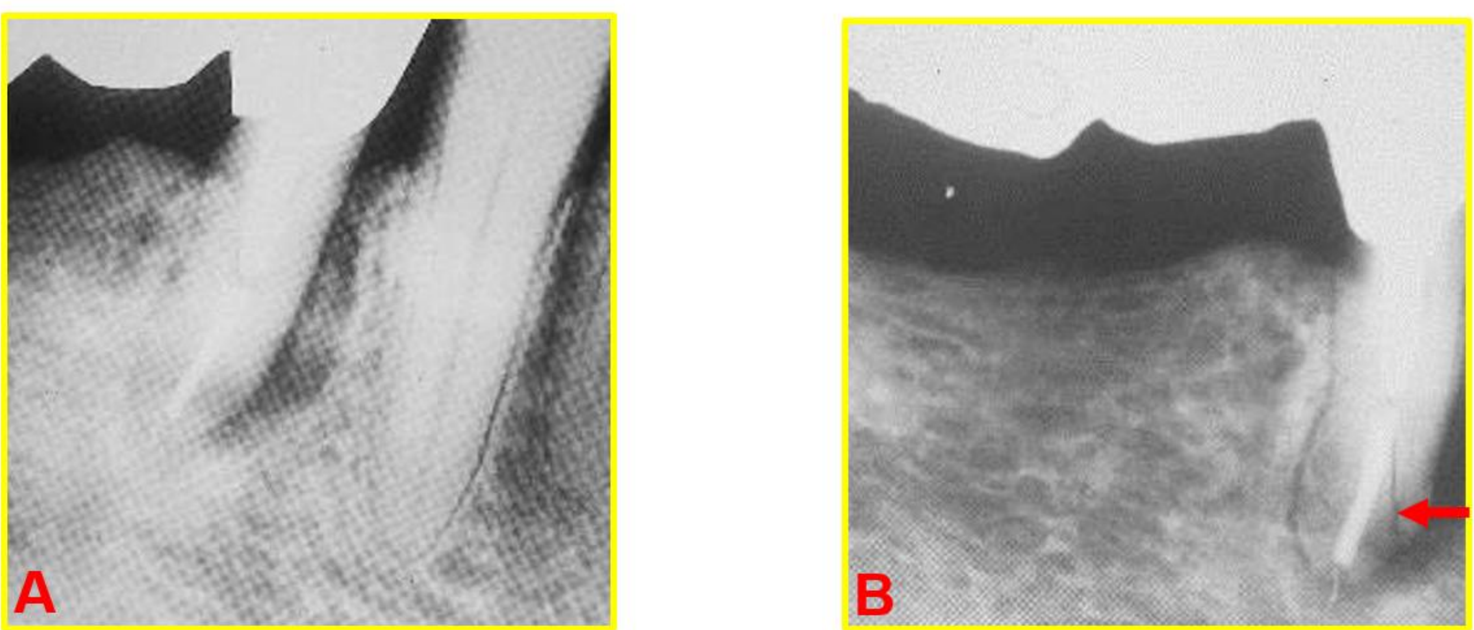


Figure 24: J- shaped vertical root fracture (A straigh-on projection, B mesial projection.)

Figure 25: Retrograde restoration (A), which have been dislodged one year later indicating a vertical fracture (B,C).

Figure 26: A disproportionate widening of a canal space compared with the same tooth or adjacent teeth (vertical fracture).

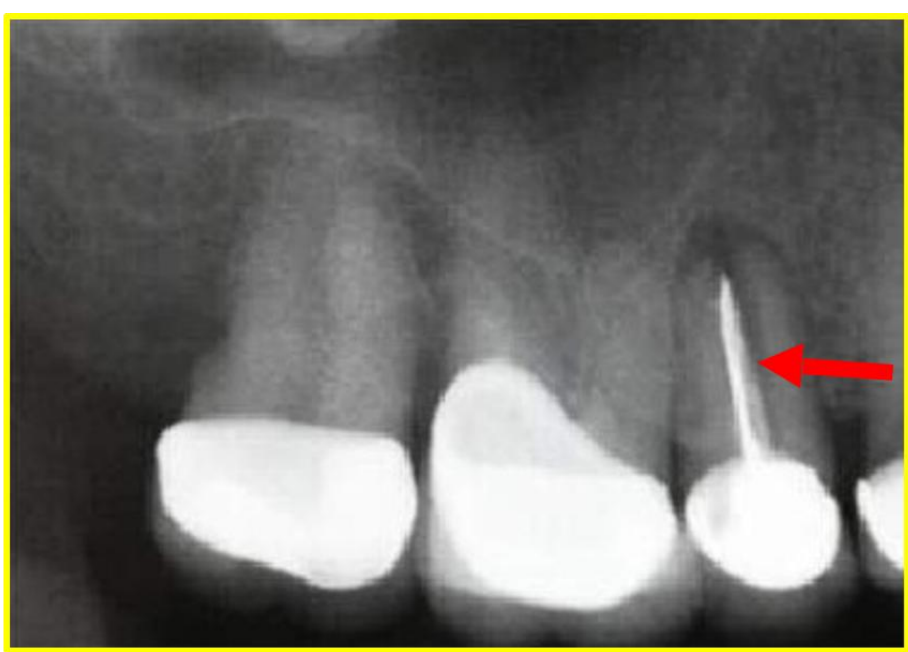
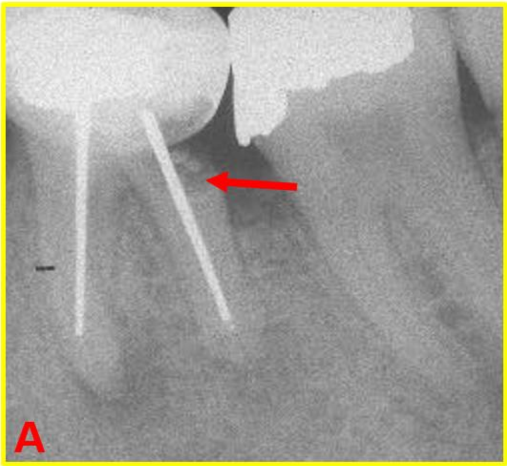
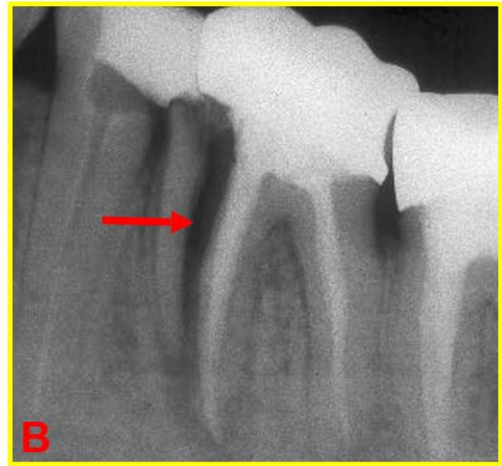


Figure 27: A space between obturation and the canal wall (split tooth). A Root separation Vertical fracture



A Root separation



Vertical fracture

Root perforation

Figure 28: Treatment errors (A-C).

Figure 29: Radiograph was taken after repositioning and suturing the flap (A, B)

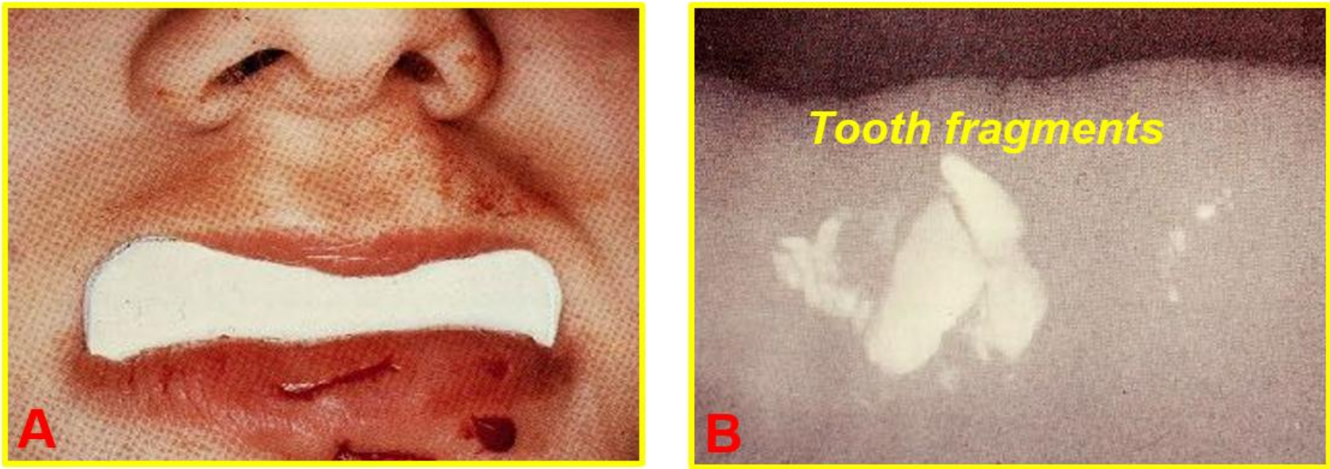


Figure 30: Exposure time is 25% of the normal (A, B).

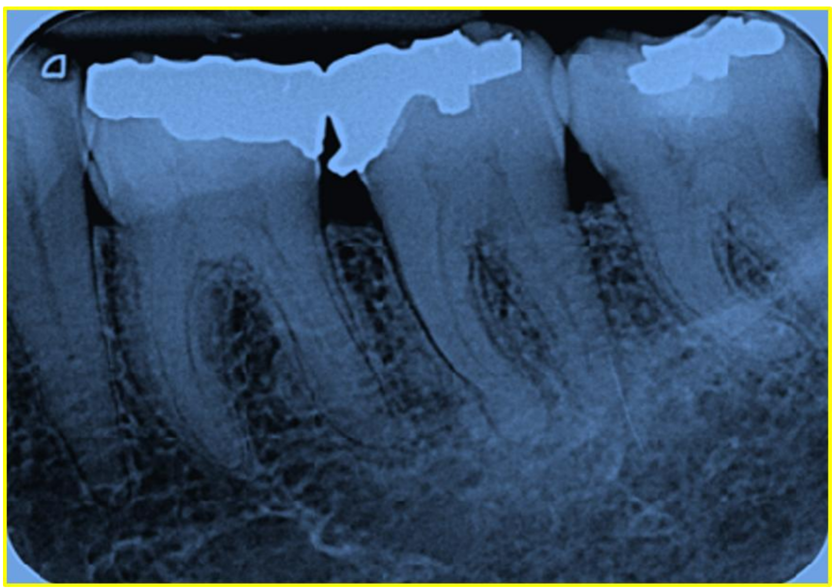


Figure 31: Periapical radiograph showing no obvious pathology.

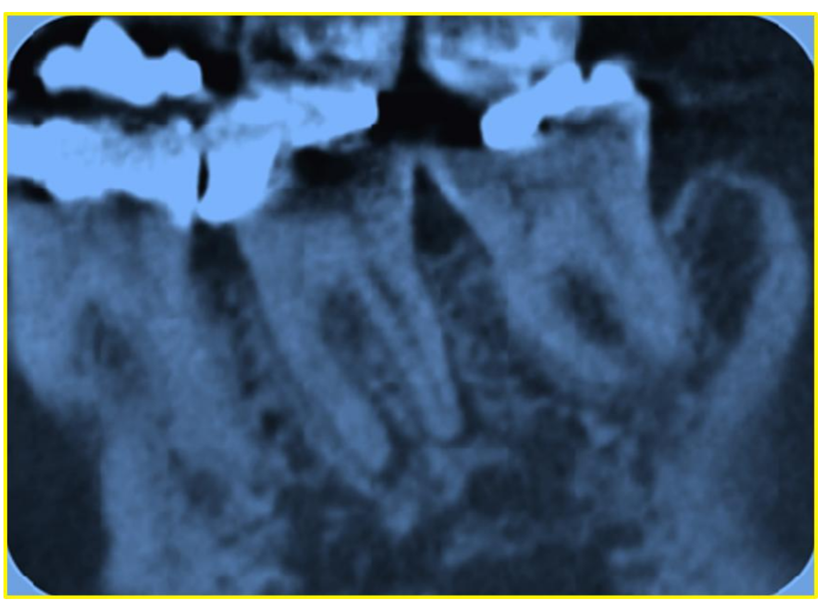
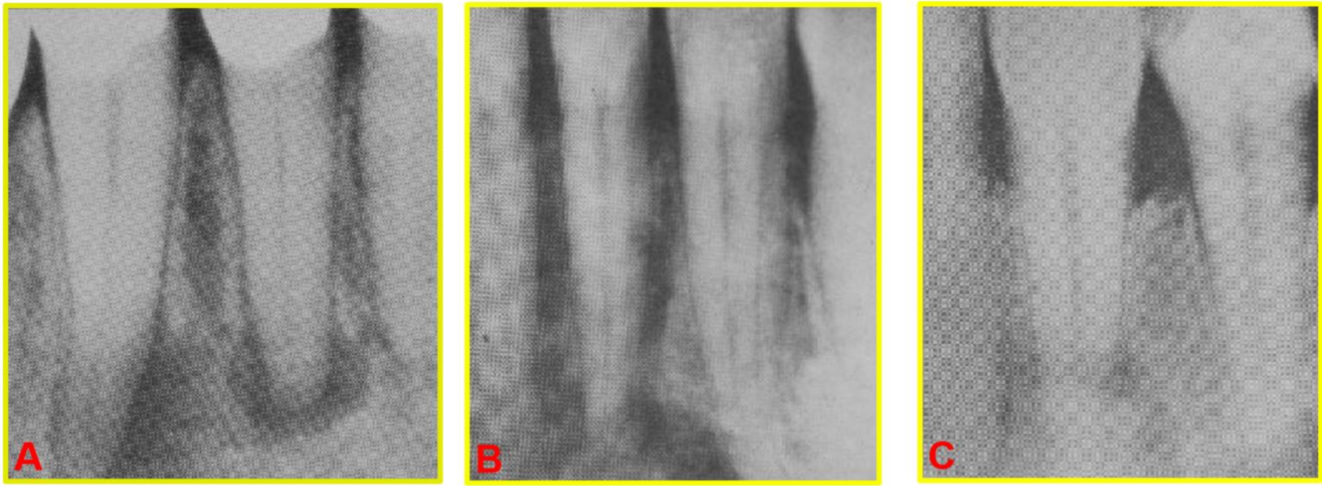


Figure 32: CBCT imaging (sagittal view) showing periapical pathology.



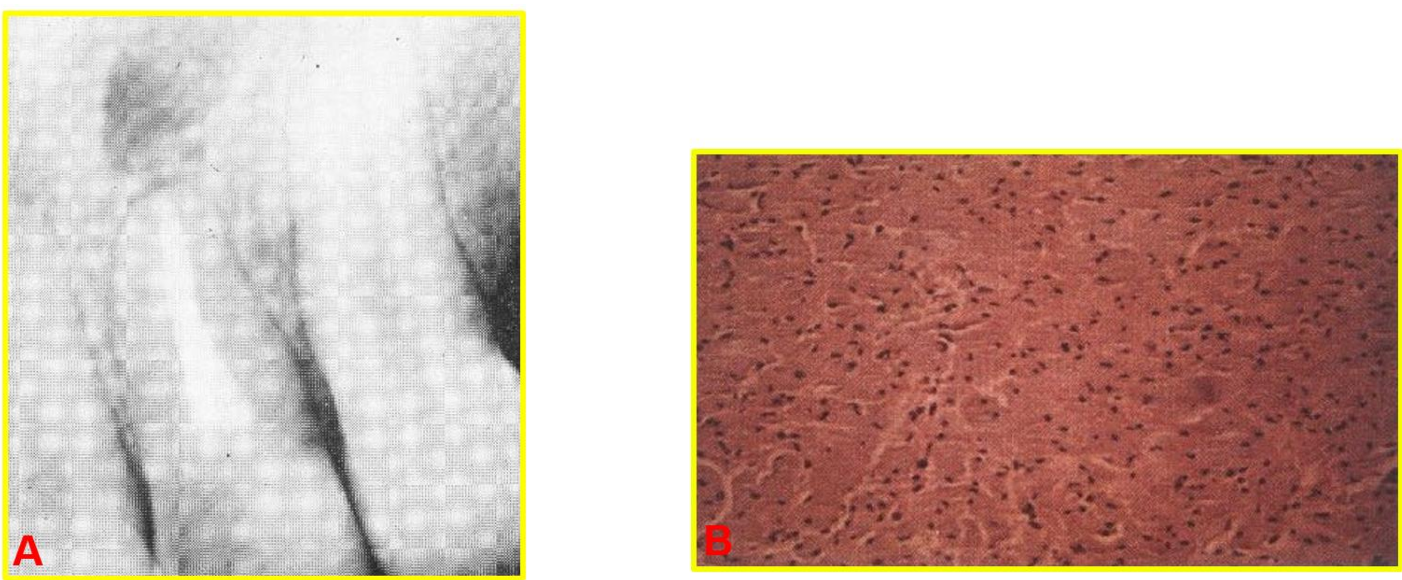
A. Osteolytic stage

B. Cementoblastic or intermediate stage

C. Mature stage

- **Asymptomatic odontogenic benign tumor.**
- **Etiology: Unknown, may be due chronic traumatic occlusion.**
- **Pulp testing: Tooth vital and normal.**
- **Radiographically: Three stages**
- **Treatment: Periodic observation, it is harmless.**

Figure 33: Clinical case; Cementoma, (A, B, C)



- Asymptomatic radiolucent area
- Previous apical surgery 10 yrs earlier
- Intact PDL
- Intact LD
- Healing by scar tissue

Fibrous connective tissue
(no inflammatory cells)

Figure 34: Follow-up radiograph, 10 yrs. Post-operatively. (Chronic inflammatory tissue can't be differentiated from healed fibrous scar tissue A, B).

Panoramic Radiography (OPG or Orthopantographs)

Panoramic radiography records the maxilla, mandible, teeth, maxillary sinuses and temporomandibular joint region on a single image. According to numerous investigators, it is valuable as an overview examination for facial deformity, orthodontic and implant planning, impacted teeth, jaw pathology, fractures and assessment of dental development. In endodontics, however, its lower spatial detail means that it is generally less suitable than intraoral periapical imaging for precise evaluation of the pulp space, root canal anatomy and periradicular tissues. It may nevertheless reveal unsuspected disease or indicate the need for targeted periapical examination. Finally, it tracking the position and growth of both baby and permanent teeth in children adolescents (Fig. 35-39) [1,2,16-19,21-23].

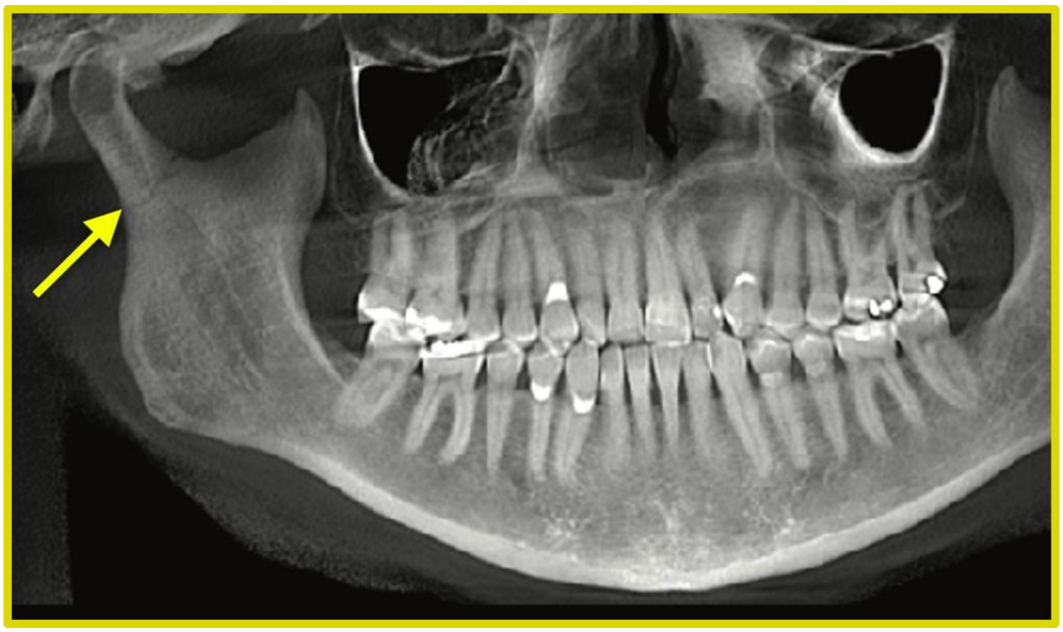


Figure 35: Panoramic radiograph shows a non-displaced fracture (arrow) through the buccal and lingual cortices of the right condyle.

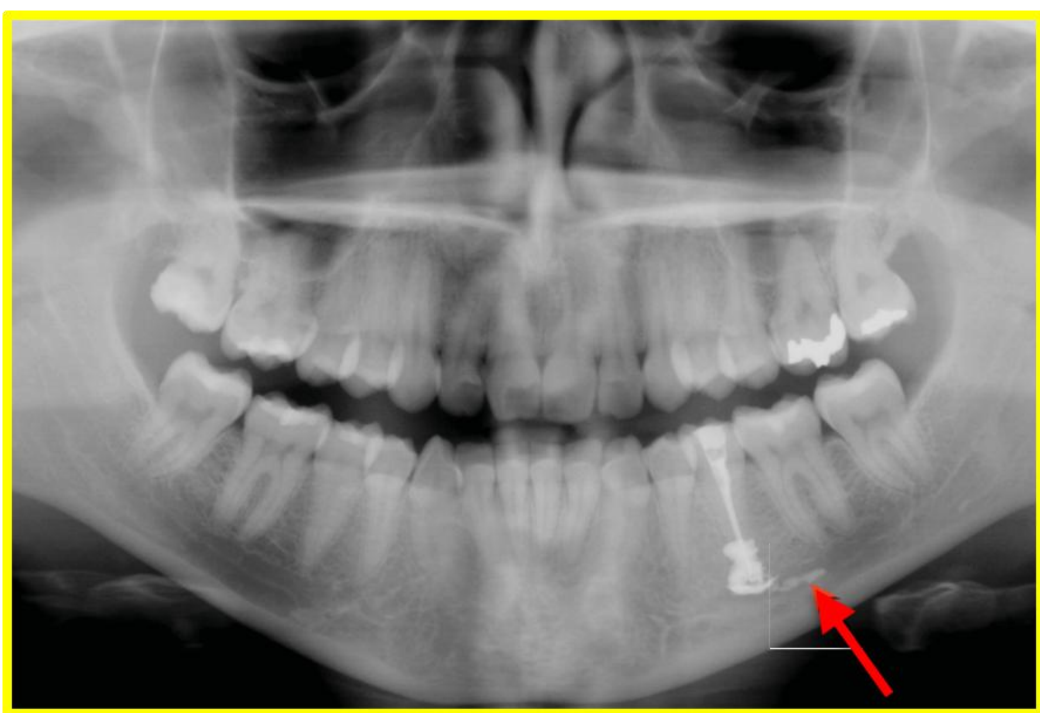
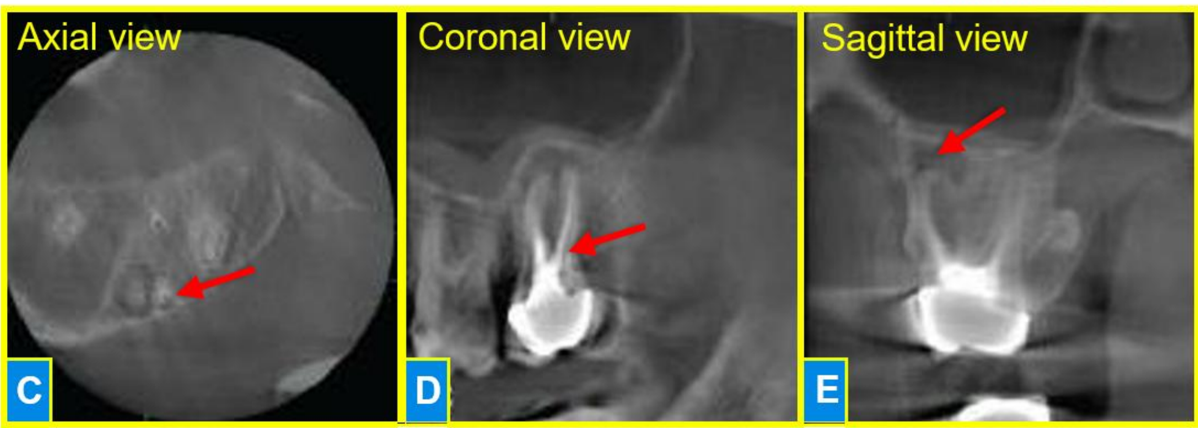


Figure 36: The patient complaining of pain, paresthesia of the left side of the mandible and lower lip, shortly after RCT. Note; extrusion of sealer into the inferior alveolar canal extending several millimeters posteriorly (arrow).

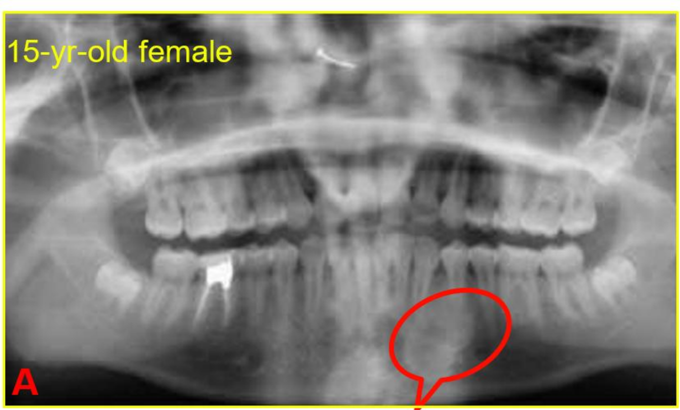
A panoramic image of the maxillary left second molar. Note; the impacted mandibular third molar (red arrow).

Periapical X ray of the maxillary second molar showing a periapical area on the mesiobuccal root



CBCT images revealed periradicular changes in all three sections especially the mesiobuccal root. Examination of this root in both the axial and coronal views showed that had two canals and only a single canal was treated.

Figure 37: A panoramic, periapical and CBCT images of maxillary left second molar (A - E).



A panoramic radiograph shows radiopacity apical to #20 to 22. No root resorption (A).

Sagittal CBCT image showing a homogeneous area of hyperdensity with irregular outline and no root resorption.

Figure 38: Idiopathic osteosclerosis (A, B).

Figure 39: A panoramic radiograph locating the mental foramen (red arrow) which was not visible on a standard periapical radiograph.

RadioVisioGraphy (RVG)

RVG is a direct digital intraoral radiographic system in which an electronic sensor replaces conventional film. The acquired image is displayed rapidly on a computer and can be duplicated, stored, retrieved, transmitted, enlarged and adjusted for viewing. Wired detectors prevent their swallowing and ingestion. The system includes a sensor, an X-ray source and computer hardware and software. Published work has shown diagnostic performance broadly comparable with conventional intraoral film while providing the workflow advantages of digital acquisition [2,24].

More reported advantages of digital intraoral imaging include reduced radiation requirements with many sensor systems (50% to 80% less than traditional film), immediate image availability without chemical processing, post-acquisition adjustment of brightness and magnification, easier storage and communication with other specialists, assistance with working-length and treatment assessment, evaluation of periodontal bone changes, support for implant planning and the ability to retain patient and exposure metadata. Furthermore, it can be colorized which useful for patient education and reusable sensors also reduce film-processing consumables, although the magnitude of dose reduction and other benefits depends on the equipment and technique used. Finally, multiple exposure from various angles without moving the sensor (Fig. 40-42) [1,2,20-35].

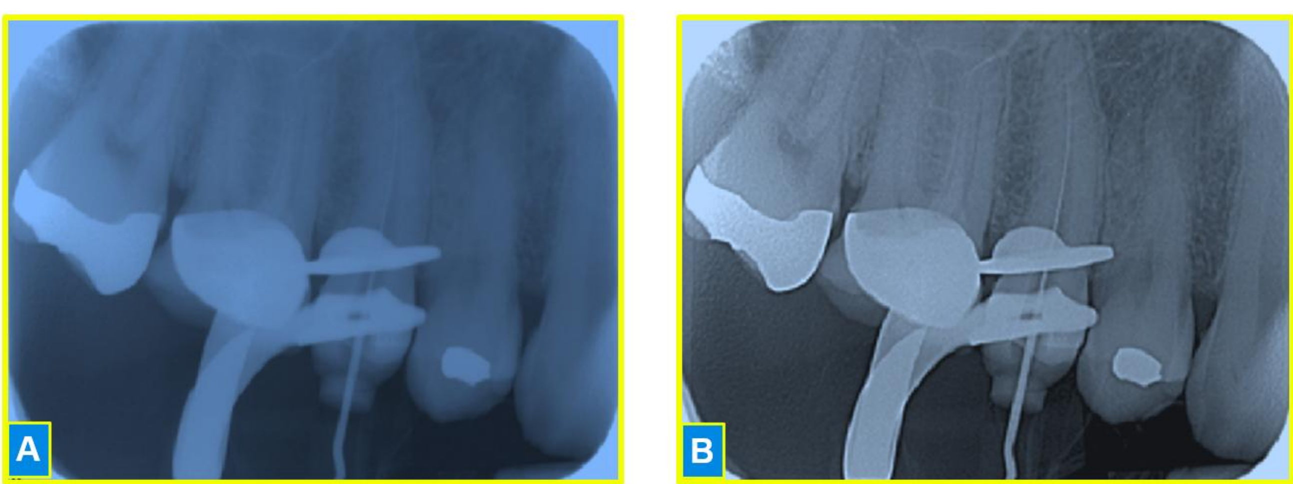


Figure 40: Images of working length file without enhancement (A); with high-pass sharpness filter applied (B).

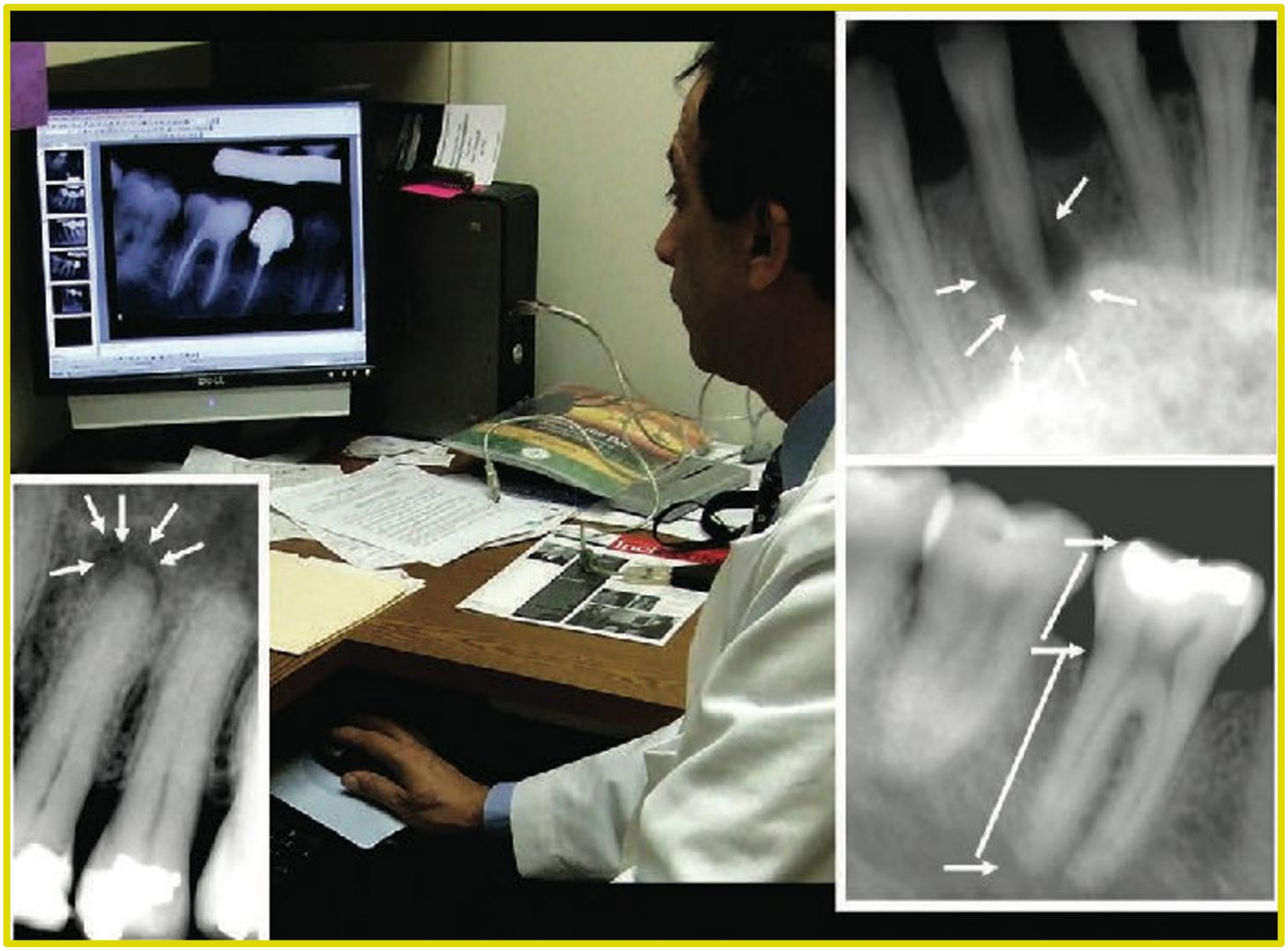


Figure 41: Endodontic evaluations using the RVG. These details clearly demonstrate the ability of sensors to demonstrate periapical lesions and tooth length.

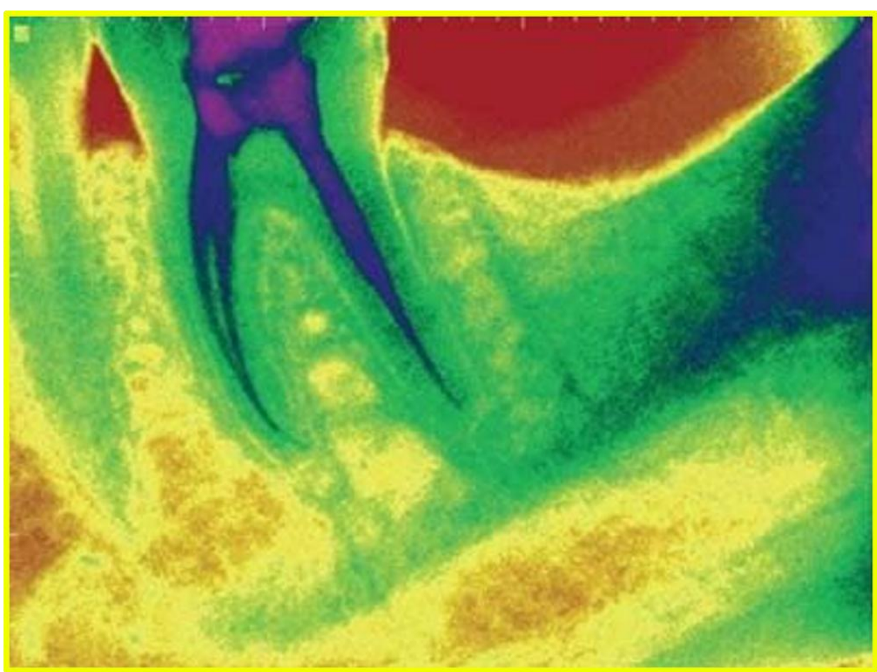


Figure 42: Digital radiography over conventional film in that the image can be enhanced and colorized. A usual tool for patient education.

Digital Subtraction Radiography

Digital subtraction radiography evaluates change between radiographs obtained at different time points. After the images have been geometrically aligned, computer processing suppresses structures that remain unchanged so that areas of loss or gain become more conspicuous. The method has been investigated for early periodontal bone changes, recurrent caries, implant integration, internal and external root resorption, periapical lesions and assessment of treatment response [36-45].

The technique is highly dependent on reproducible image geometry. Differences in projection or positioning can introduce subtraction artifacts and reduce interpretability. For this reason, although digital subtraction can detect subtle temporal changes, its routine clinical use is more demanding than conventional radiography and it has been used extensively in research settings. Note: unchanged areas (teeth, restorations) appearing as neural gray and areas of bone loss appear darker or bone gain appear lighter (Fig. 43) [36-45].

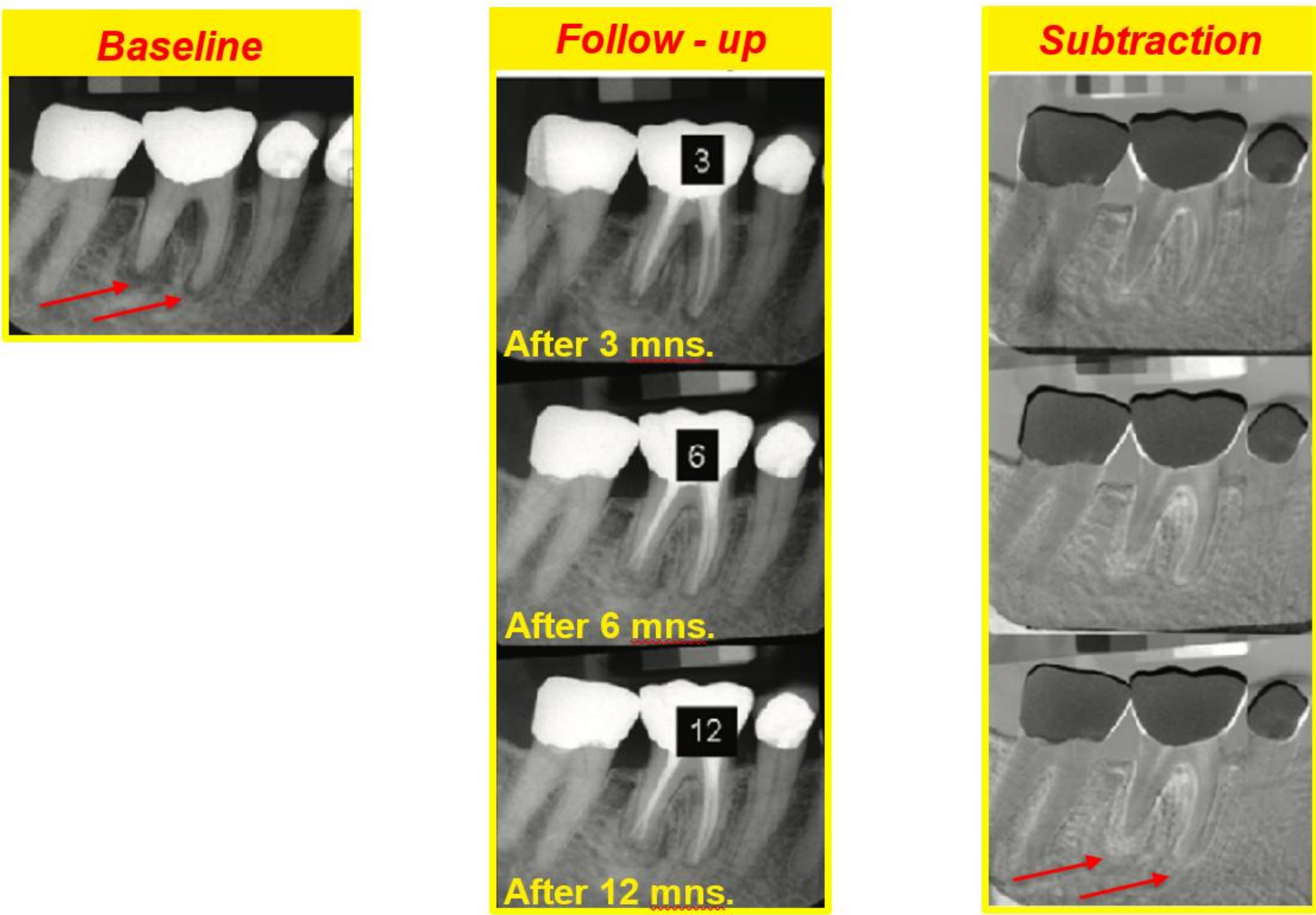


Figure 43: Digital subtraction comparing baseline (column 1) to follow-up images (column 2). Column 3 indicates subtraction of respective follow-up images from the baseline radiograph. Progressive remineralization of the radiolucency at the apex of the distal root of the 1st molar is evident.

Occlusal Radiography

Occlusal radiography provides a relatively broad intraoral view of the maxilla and palate or the mandible and floor of the mouth. A large film is positioned on the occlusal plane (size 4) is commonly used for adults and smaller film (size 2) may be selected for children. The technique can assist in localization of impacted or supernumerary teeth, jaw fractures, cystic lesions, salivary calculi, selected carious or apical lesions, nasal cavity, sinus, cleft palate and other abnormalities that are difficult to encompass on a small periapical image. It may also be useful when mouth opening or tolerance of a conventional intraoral receptor is limited. Film is placed on the occlusal plane and the X-ray beam is directed at an angle (60-70 degrees) through the jaw onto the film, capturing a cross or longitudinal jaw (Fig. 44-46) [46-51].

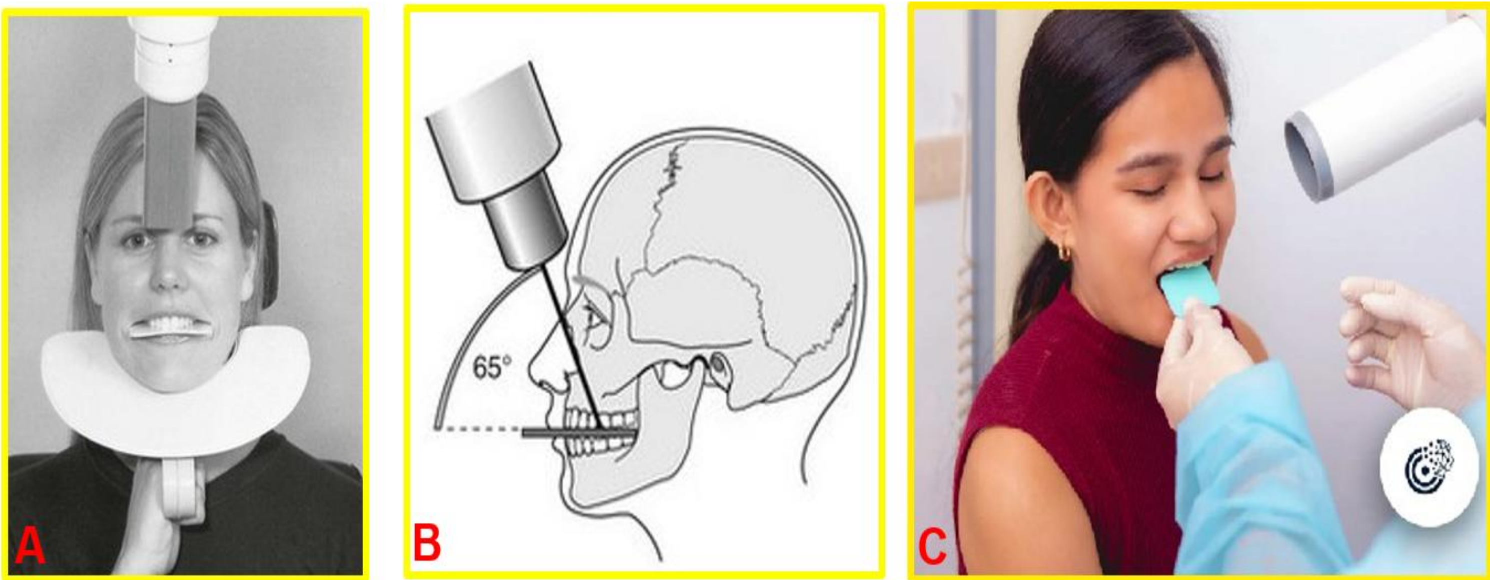


Figure 44: Maxillary occlusal projection of occlusal radiograph (A-C).

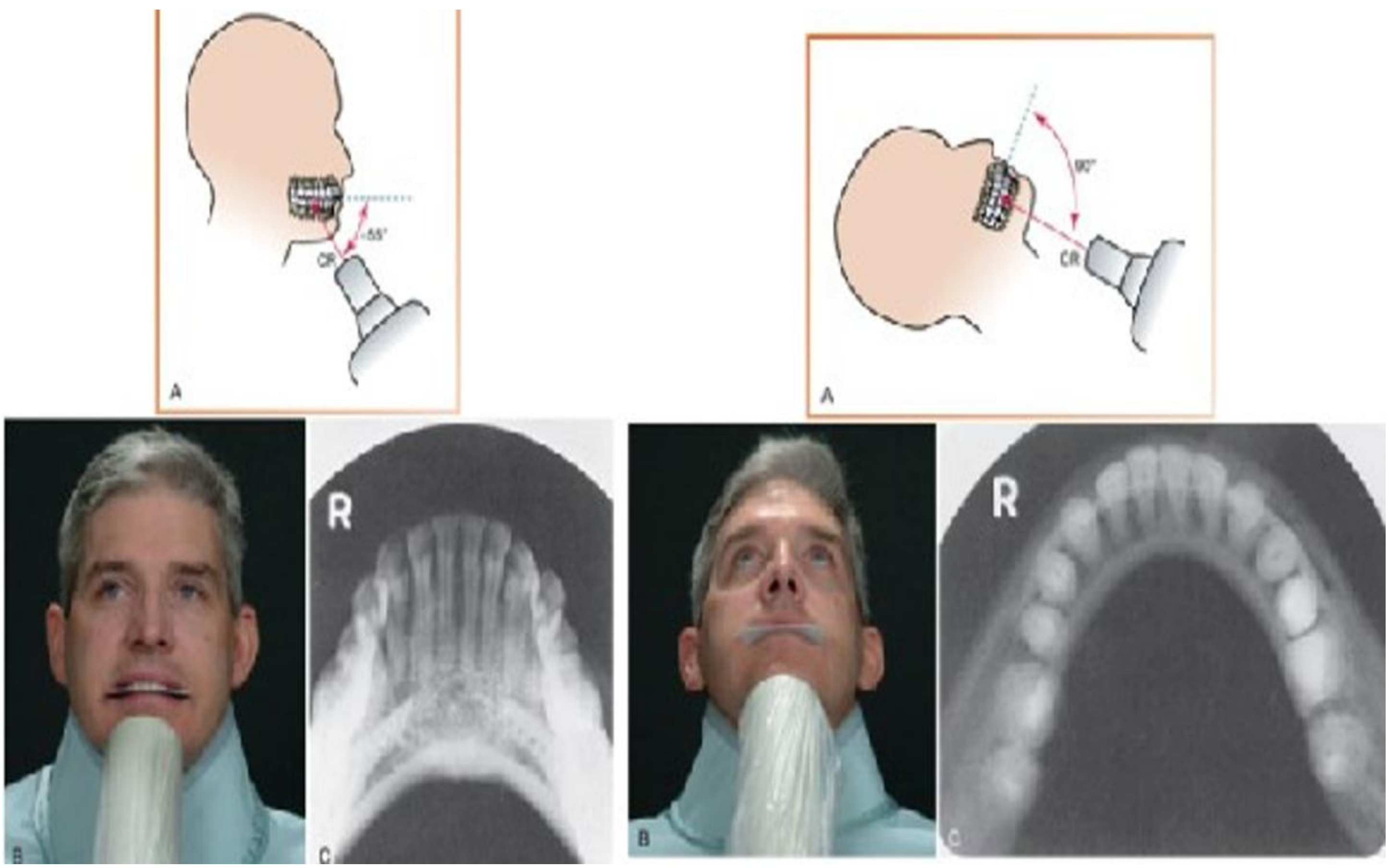
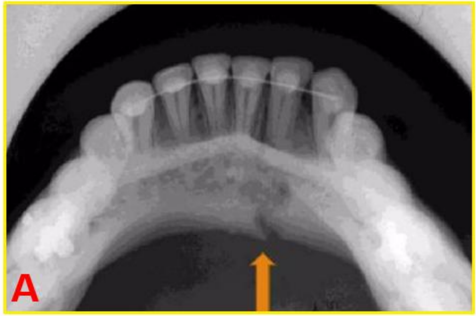
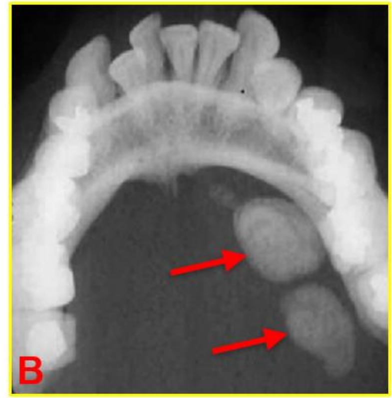


Figure 45: Mandibular occlusal projection.



Occlusal film showing fracture of mandible (A).



Showing two submandibular gland duct stones (B).

Showing impacted canine (C).

Showing Fractured anterior teeth (D).

Figure 46: Uses of occlusal radiograph (A-D).

Bitewing Radiography

Bitewing radiographs record the crowns of opposing maxillary and mandibular teeth and the adjacent crestal bone. They are particularly useful for detecting interproximal and recurrent caries below fillings, evaluating restoration margins, detecting crown fracture, identifying calculus and assessing periodontal bone levels, view how well teeth touch each other. Digital receptors can be used instead of film. Horizontal bitewings are commonly used for posterior caries assessment, whereas vertical bitewings provide greater coverage of the alveolar bone and are useful when periodontal bone loss is present (Fig. 47-49) [19,52-61].

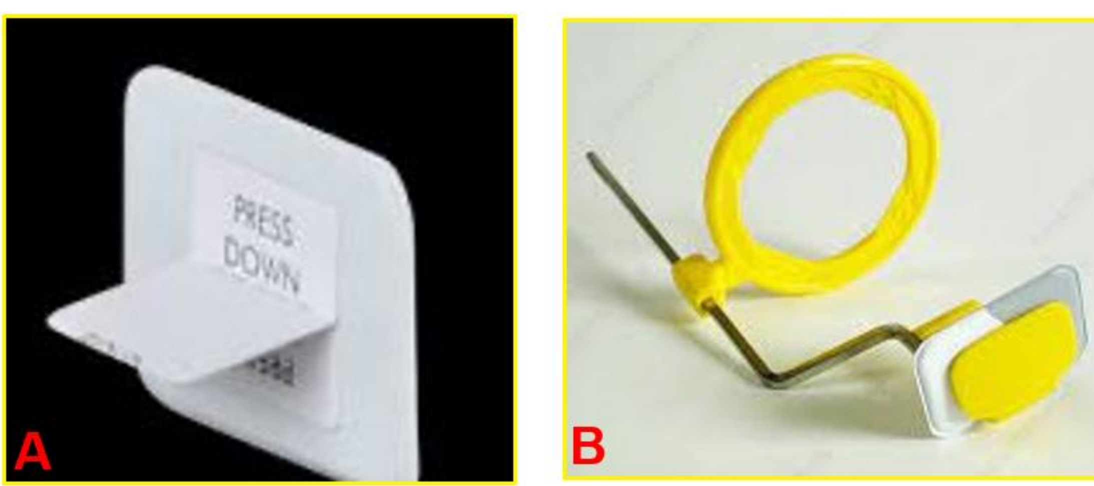


Figure 47: Bitewing film holders (A, B).

Figure 48: Digital sensor.

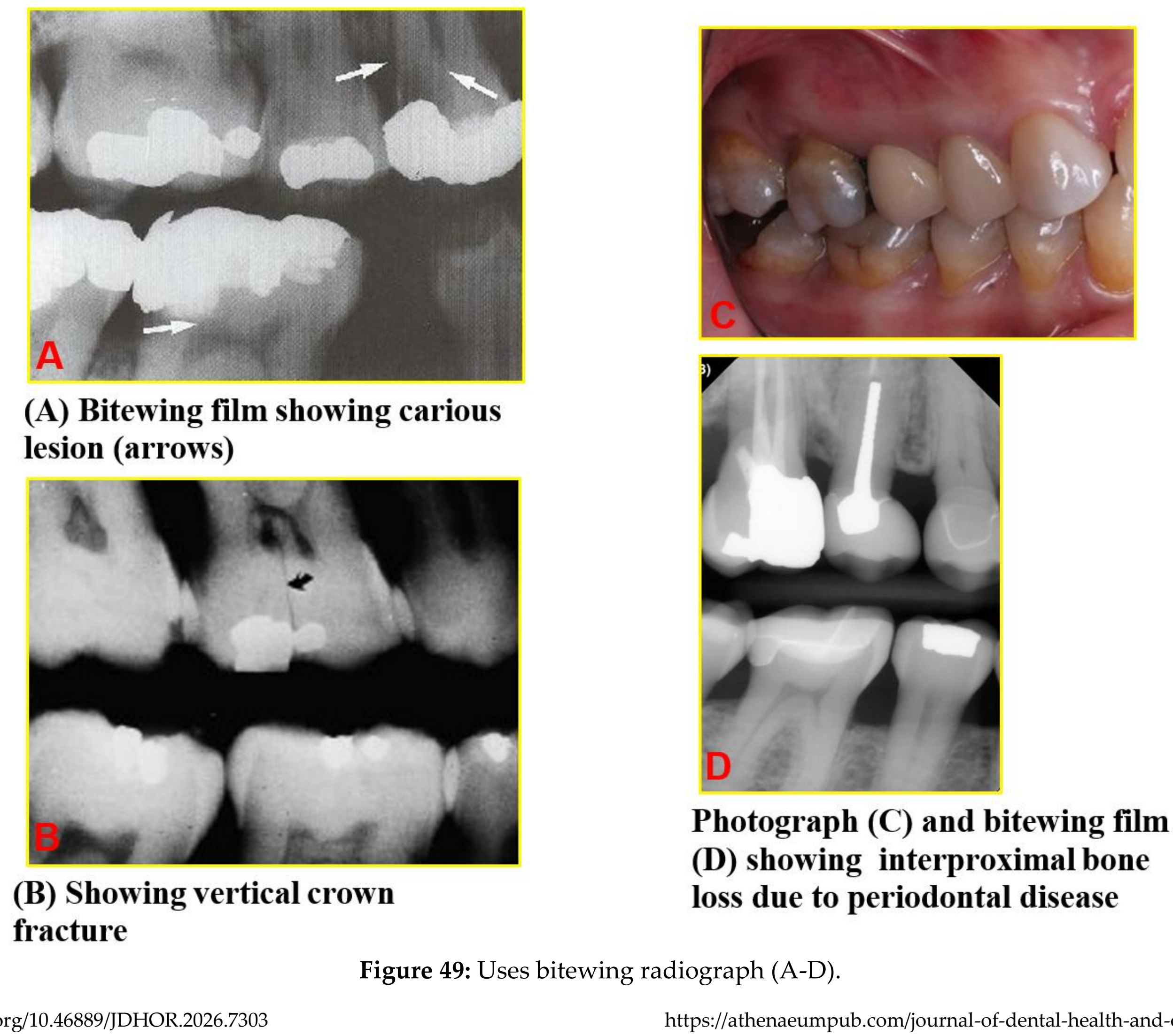


Figure 49: Uses bitewing radiograph (A-D).

Three-Dimensional Imaging

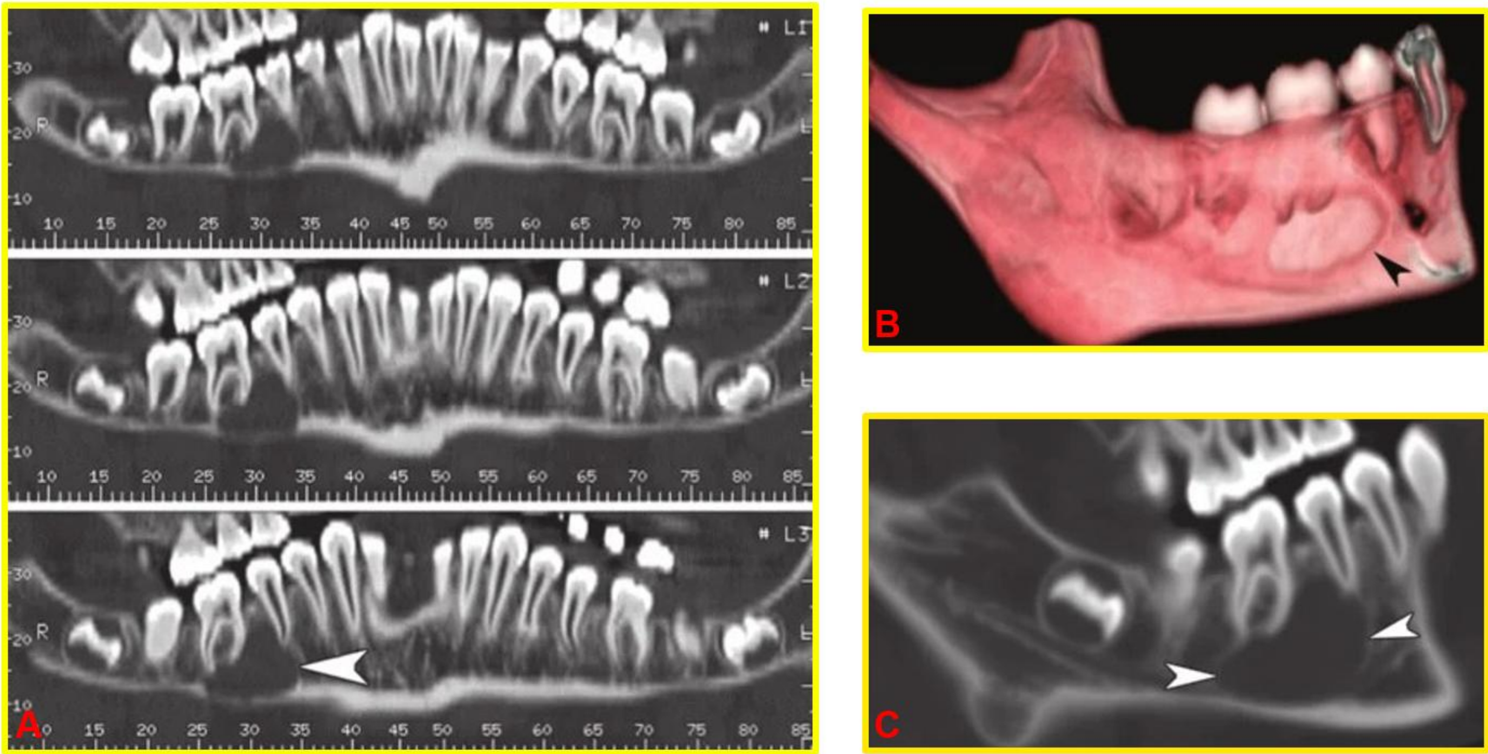
Digital 2D radiography allows image enhancement and rapid acquisition, but some anatomical relationships and subtle changes remain difficult to evaluate when structures are superimposed. Bone fill can be detected using more sensitive techniques such as digital subtraction radiography. Recently, three-dimensional techniques used in the dental and endodontic field include CT, MRI and CBCT. These modalities differ substantially in physical principles, radiation exposure, spatial and soft-tissue contrast, availability and clinical indications [1,16,43].

Computed Tomography (CT or CAT SCAN)

Computed tomography produces cross-sectional images or slices that can be reconstructed to display anatomy in three dimensions. Each slice thickness is 1-2 mm. CAT Scan developed in 1972 in U.K. by Sir Godfrey Hounsfield who earned the "Noble prize" for medicine. CT as stated by numerous studies, can be used as an adjunct when information about teeth, surrounding bone or adjacent periradicular structures cannot be obtained adequately from conventional radiography especially in surgery. In dentistry and maxillofacial practice it has applications in assessment of alveolar fractures, oral cavity tumors, blood clots and infection (pneumonia), internal injuries, implant-site bone volume and localization of impacted teeth. CT is faster than MIR and provide more details than conventional X-rays. In addition, portable CT scanner is now available in intensive care units, operating rooms and ambulance. However, they are not required for the routine diagnosis of the vast majority of teeth due to high costs, high radiation exposure and poor resolution than conventional radiographs and the availability of dental-specific alternatives such as CBCT (Fig. 50-53) [19,62-66].

Figure 50: Tomography means an image of a sections of human body. Each slice thickness 1-2 mm.

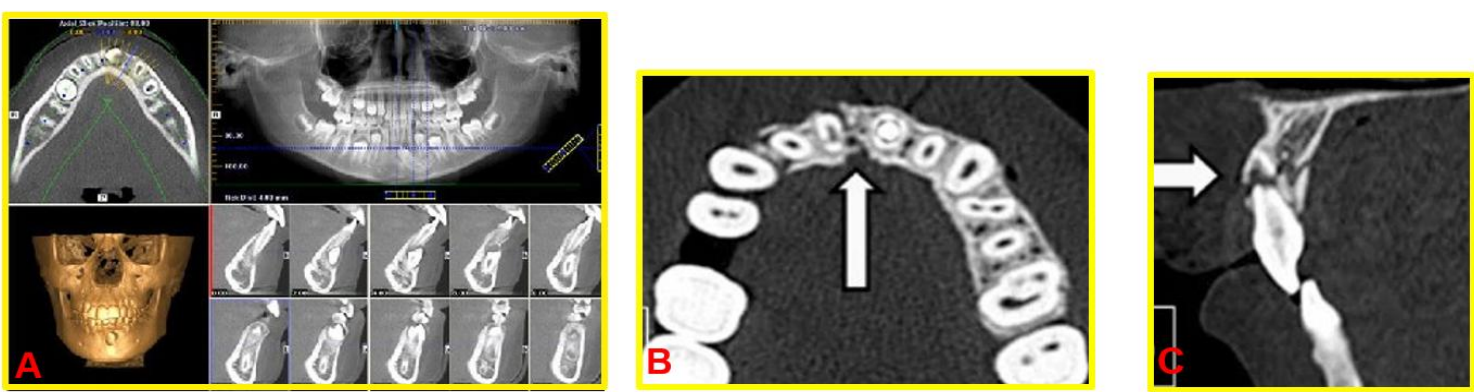
Figure 51: CT which uses specialized X-ray equipment and advanced computer processing to create detailed cross-sectional images of the body.



(A) Dental images (panoramic view) show normal teeth. Note the radiolucent expansile lesion in the posterior zone (arrowhead). Histologic analysis revealed an aneurysmal bone cyst.

(B) lesion enlarged. (C) CT image shows the location of the lesion (arrowheads).

Figure 52: Uses of CT; appearance of teeth and periapical lesion (A - C).



Impacted canines - axial (A)

Upper alveolar process fracture, axial (B) and sagittal (C) with associated root fracture (arrow).

Figure 53: Uses of CT; Impacted canine(A), upper alveolar bone (B) and root fracture (C).

Magnetic Resonance Imaging (MRI)

MRI generates images using powerful magnets and radiowaves with magnetic fields and radiofrequency signals rather than ionizing radiation. It provides strong soft-tissue contrast and can produce multiplanar or three-dimensional anatomical information. Compared with CT, its physical basis and tissue contrast are different and the presence of certain implanted electronic or ferromagnetic devices may restrict its use [67-70]. In the endodontic and dental literature, MRI has been investigated for visualization of pulp anatomy and vitality, assessment of carious involvement and infection such as periapical abscess and osteomyelitis, temporomandibular joint disorders and selected surgical or implant-planning applications. Its role in routine endodontics remains limited (Fig. 54,55) [19,67-78].

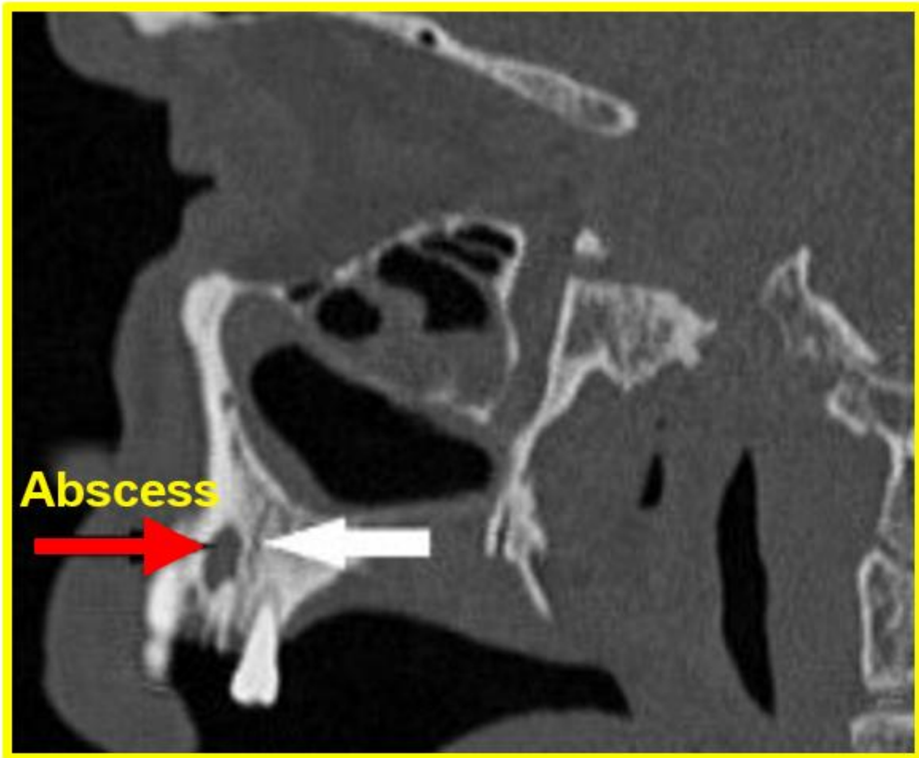


Figure 54: Sagittal image showing periapical abscess surrounding the retained root of first premolar. Note; the fracture line crossing the alveolar process (white arrow).

Figure 55: Detection of carious lesion using MRI (yellow arrow).

Cone-Beam Computed Tomography (CBCT)

CBCT was introduced in the 1st decade of the 21th century into dental practice and later in endodontics as a volumetric X-ray technique designed for high-contrast maxillofacial structures. A cone-shaped beam and detector rotate around the patient, acquiring projection data that are reconstructed by software into a volumetric dataset. The volume can then be examined in axial, coronal, sagittal and other reconstructed planes. Compared with conventional medical CT, dental CBCT systems can provide high spatial detail for teeth and bone with smaller equipment and, depending on the protocol, a lower radiation burden [1,2,15,16,19,22,79,80].

The principal advantages of CBCT in endodontics are the elimination of anatomical superimposition and the ability to inspect structures in multiple planes. Scan times are relatively short and limited fields of view can be selected for many dental applications. The additional anatomical information can influence diagnosis and treatment planning, particularly in complex cases [1,2,15,16,19,79-81].

Reported endodontic applications include assessment of unusual root and canal morphology, canal curvature, missed or calcified canals, periapical disease not clearly demonstrated on conventional images, perforations and other treatment complications, traumatic dental injuries, horizontal and vertical root fractures, internal and external resorption and presurgical evaluation of the relationship between root apices and structures such as the maxillary sinus, inferior alveolar canal and mental foramen. CBCT has also been used to assess periapical healing, investigate root-canal volume before and after instrumentation and assist case selection for procedures such as intentional replantation (Fig. 56-69) [7,79-96].

Figure 56: CBCT, using the 3D Accuitomo 80.

Figure 57: Patient undergoing facial X-ray.

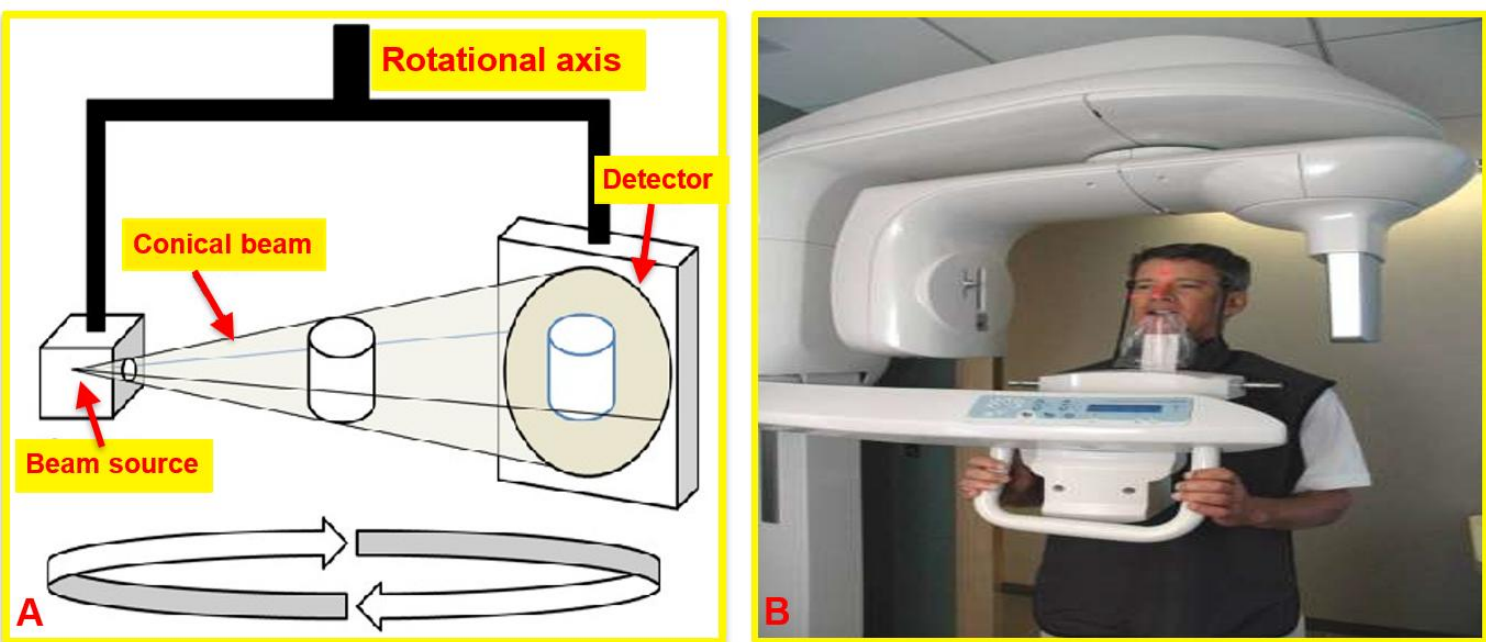


Figure 58: The X-ray source and detector rotate around a fixed fulcrum within the region of interest (A, B).

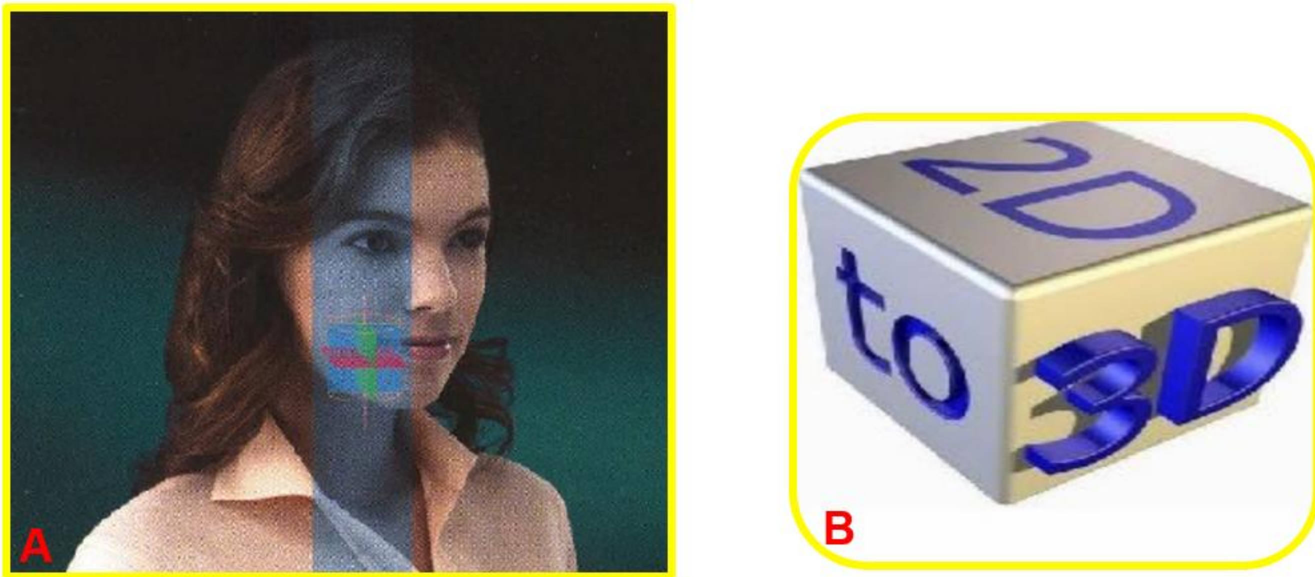


Figure 59: CBCT has the ability to capture, store, and present radiographic images in various horizontal and vertical planes (A,B).

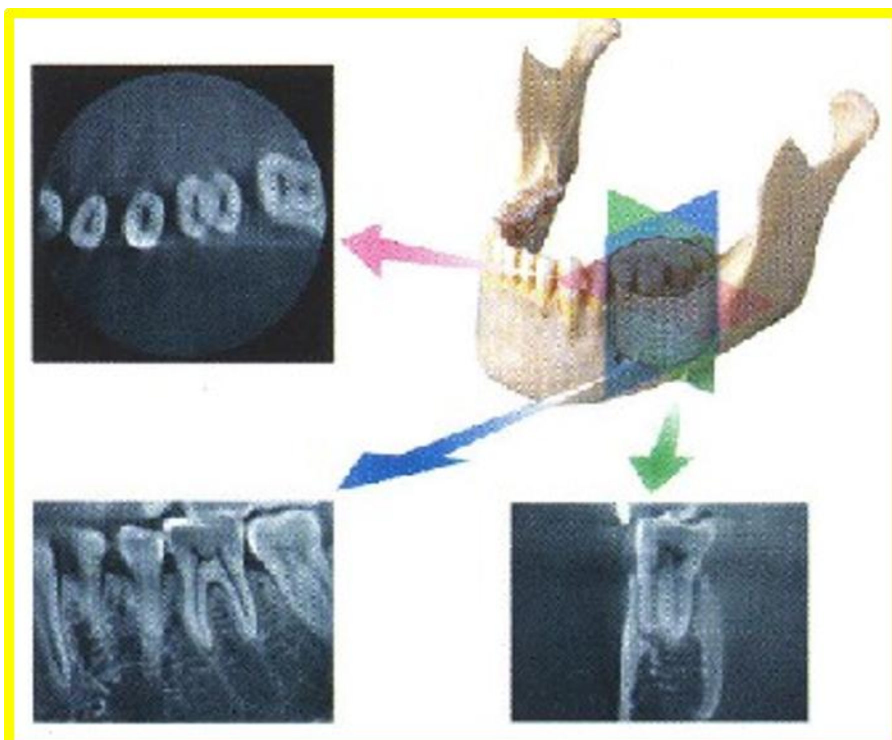


Figure 60: CBCT able to detect pathosis i bone or associated with the teeth without the obstruction of anatomic structures. The planes of vision are axial, sagittal or coronal.

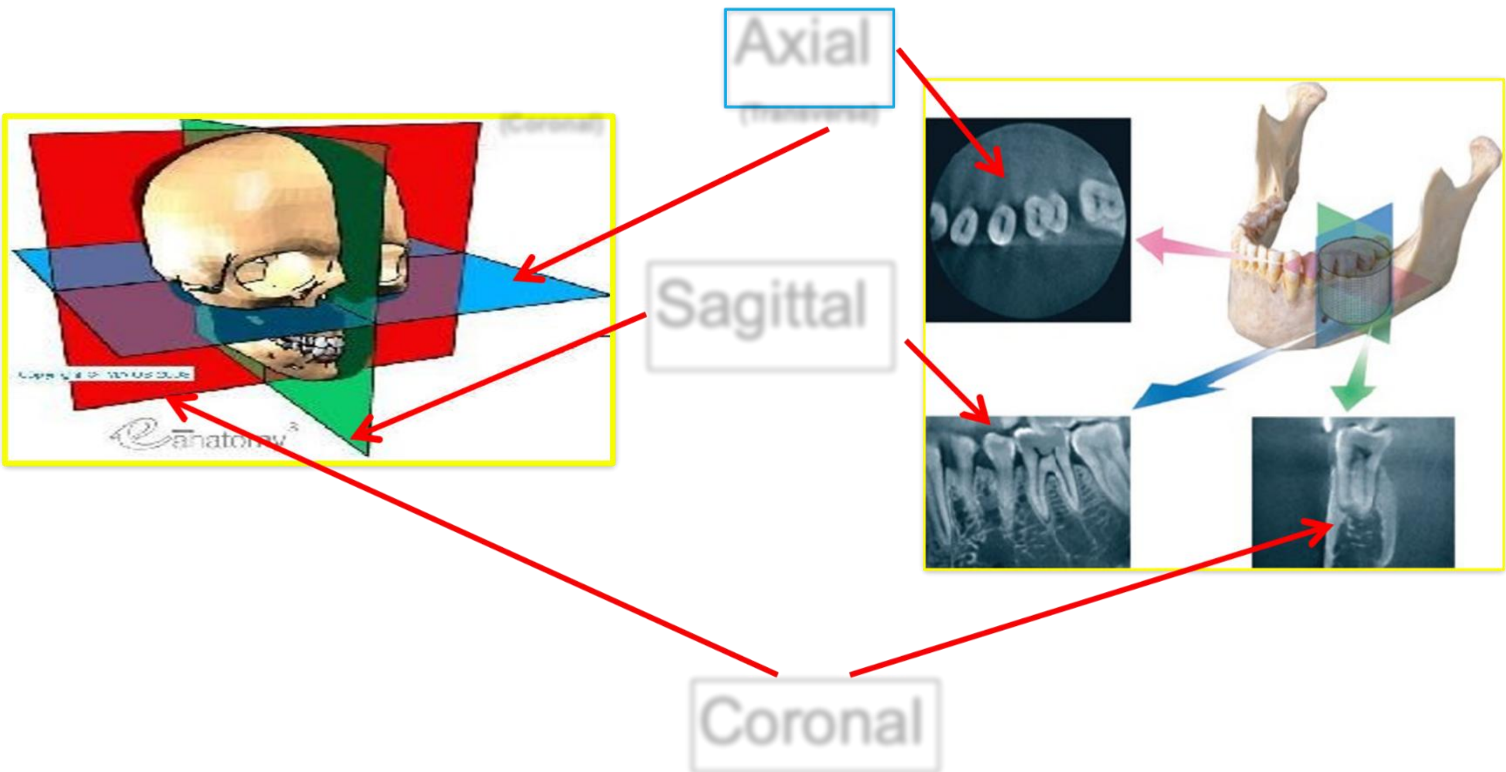


Figure 61: three-dimensional imagining of CBCT.

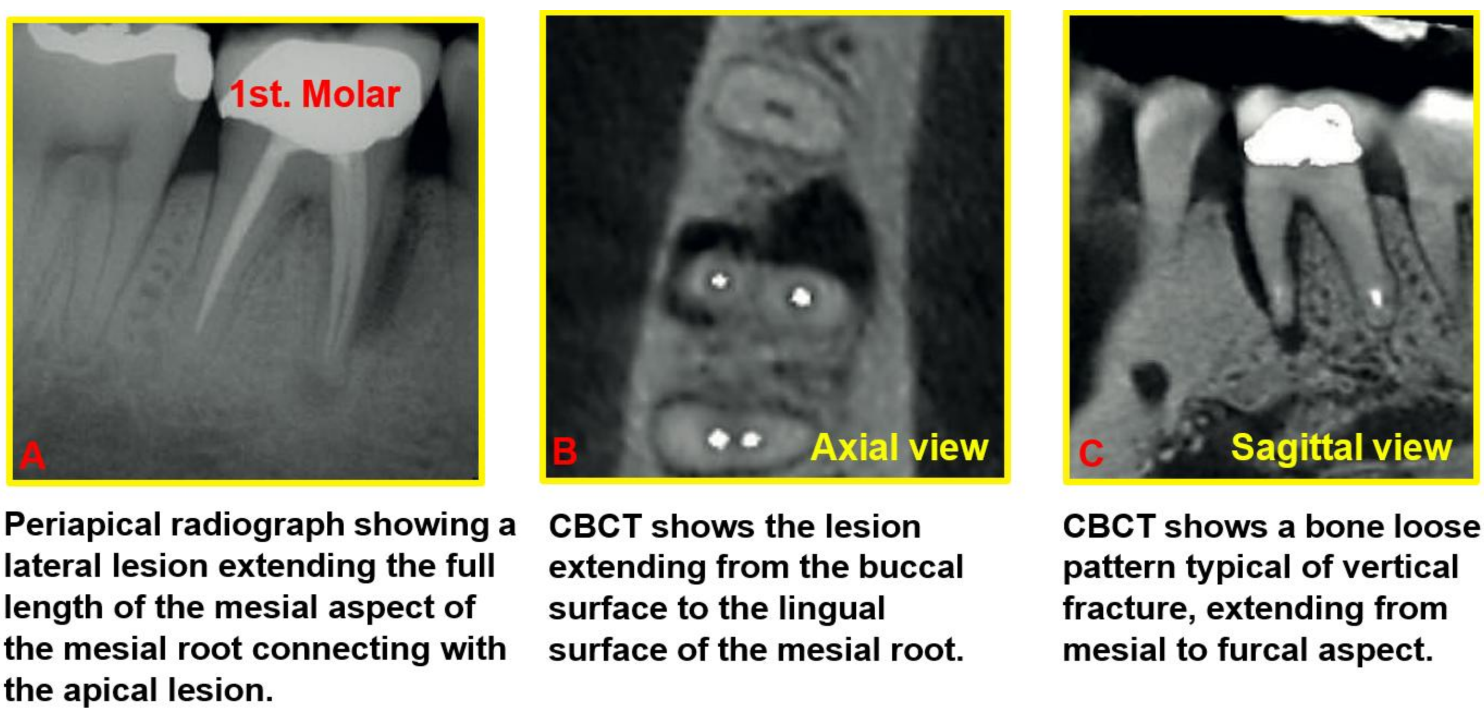


Figure 62: Extraction was advised (A,B,C).

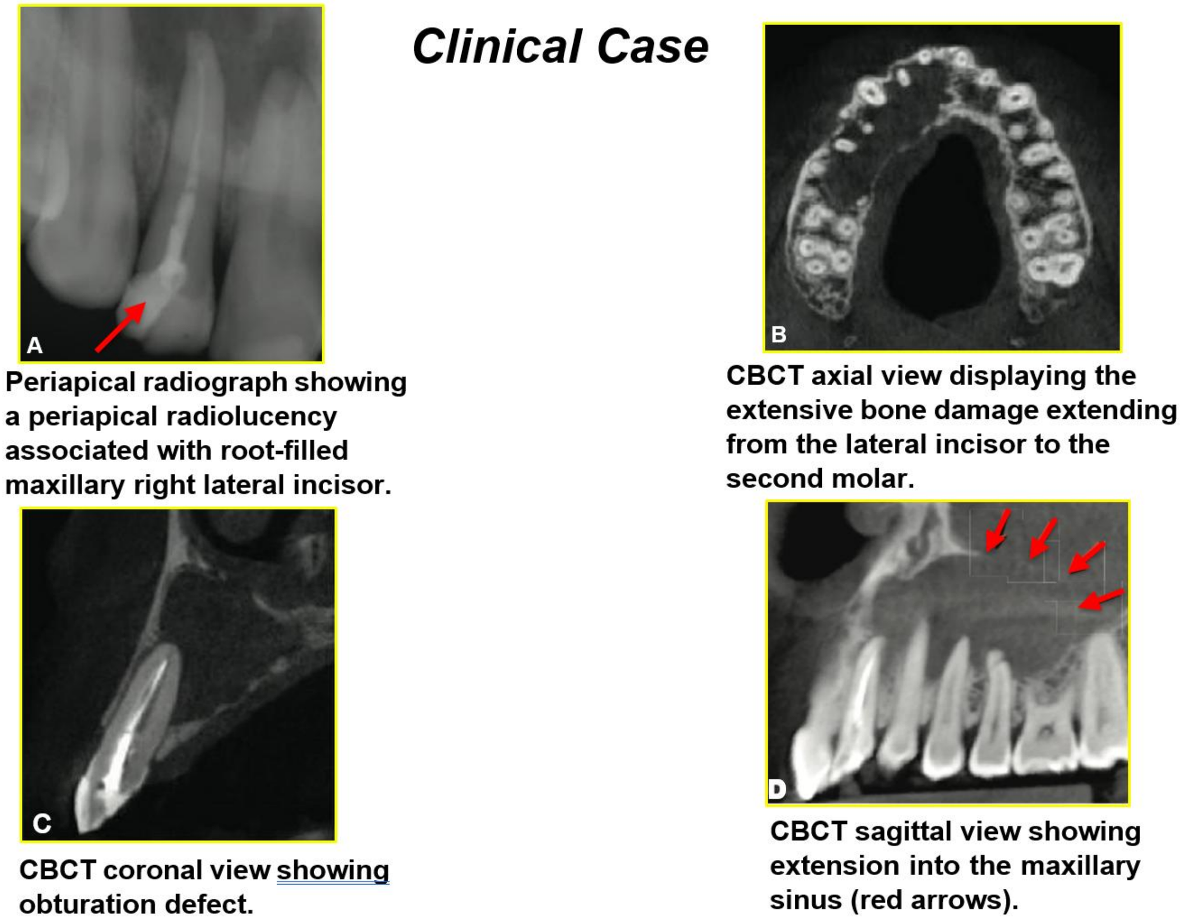


Figure 63: comparison between periapical radiograph and CBCT (A-D).

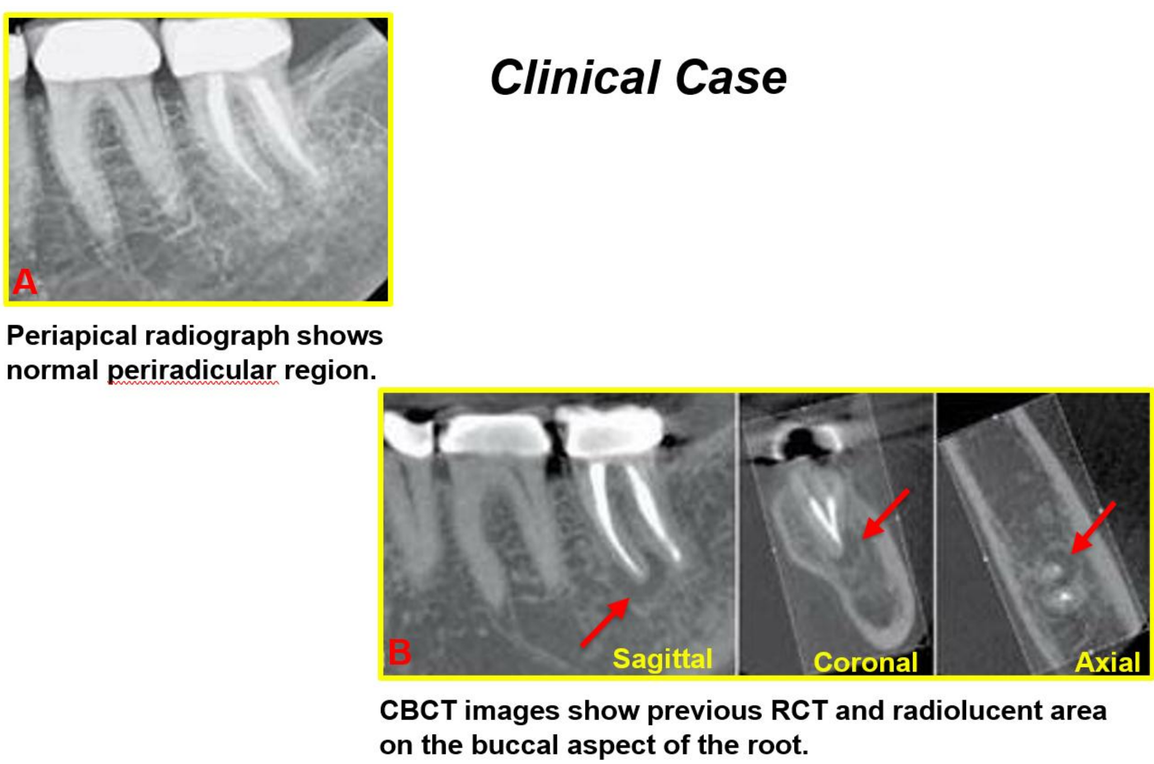


Figure 64: comparison between periapical radiograph and CBCT (A-B).

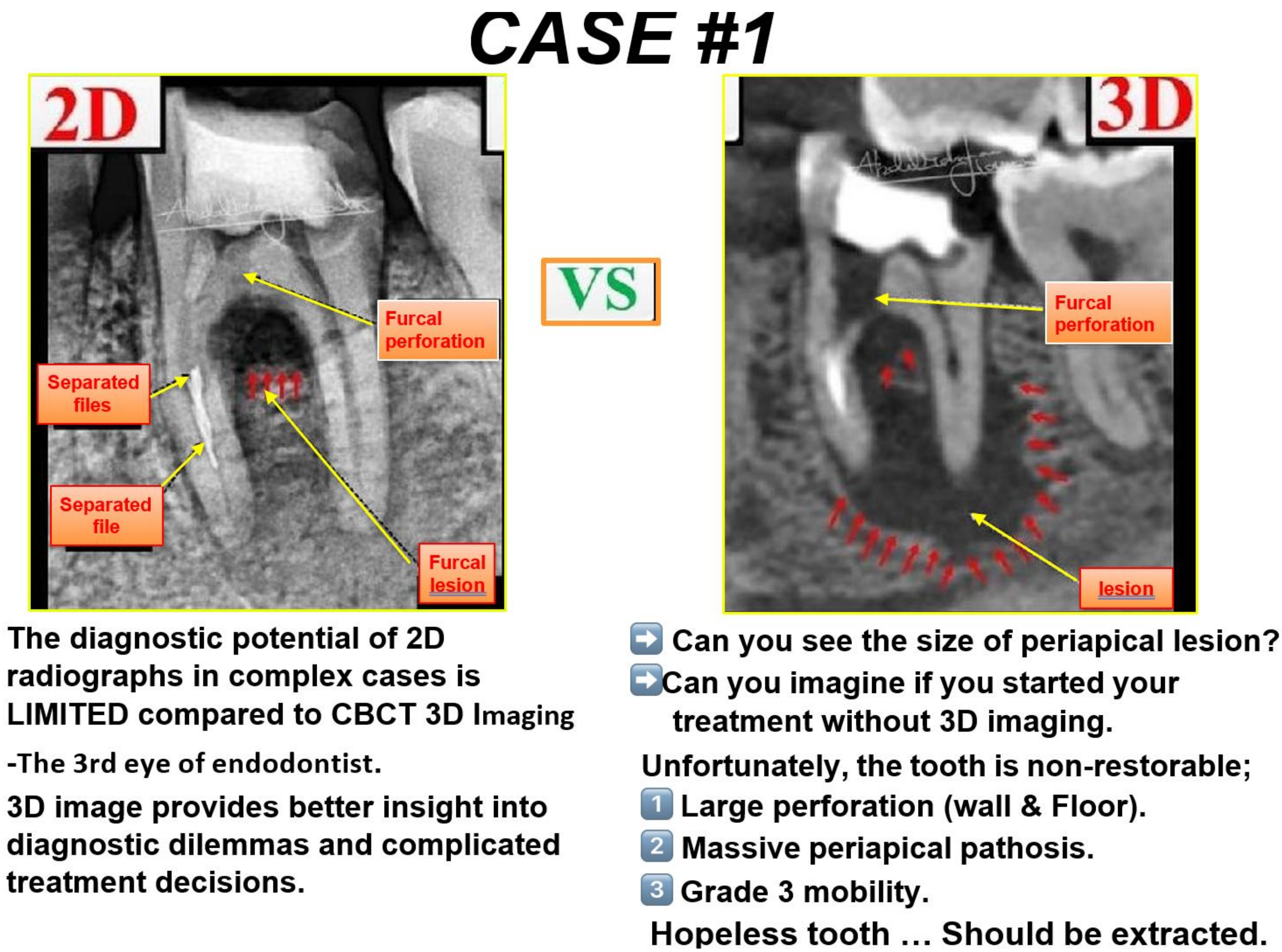
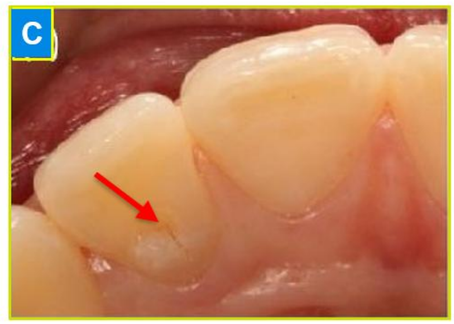


Figure 65: comparison between periapical radiograph and CBCT (A-B).

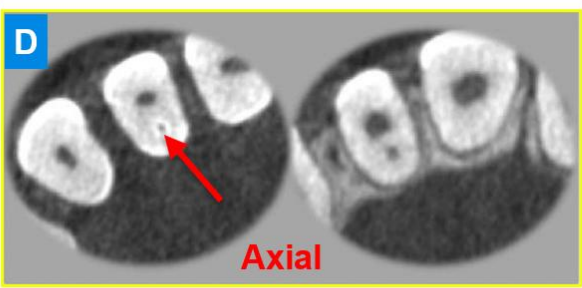
A 16-yr-old woman reported episodes of pain and swelling associated with maxillary left lateral incisor for 3 weeks. The crown was intact (A).

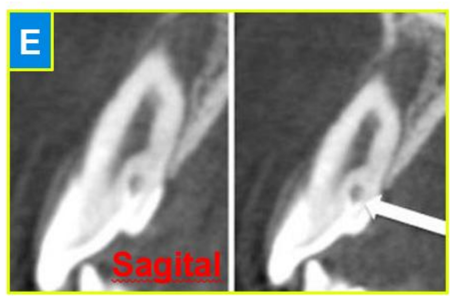
CASE # 2

The tooth was necrotic; with a normal periodontium. Periapical radiograph showed a mature tooth, and a lateral radiolucency (red arrow) (B).

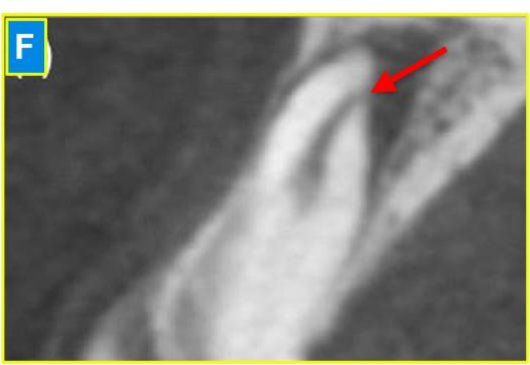


A small pit evident in the palatal surface was suspected of being a dens invaginatus (red arrow) (C).





CBCT images confirmed the diagnosis of a dens invaginatus. The axial and sagittal views showing the enamel-line invagination (red arrow) and the relationship between the main canal.



Note the lateral exit of the root canal.

Three-dimensional CBCT reconstruction; buccal view.

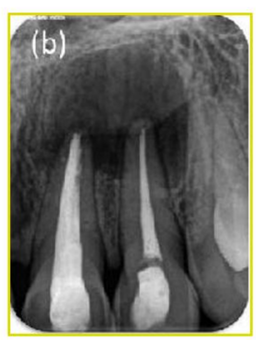
Post-operative radiograph.

A follow-up radiograph taken after 12 months. Note the complete periapical healing.

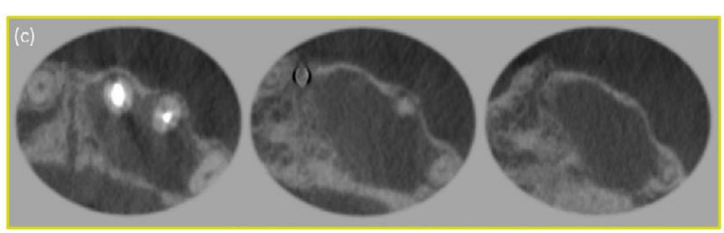
Figure 66: CBCT used in identification of root canal system anomalies such as dens invaginatus (A-I).

A clinical image of the left maxillary central and lateral incisor subjected to endodontic surgery (a).

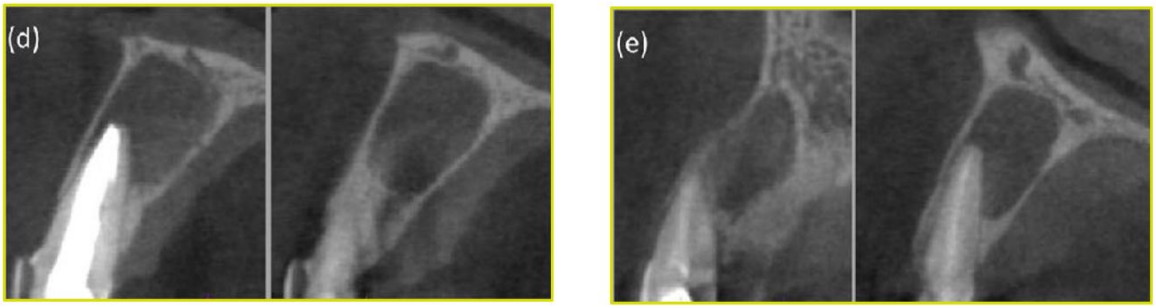
CASE # 3



A periapical radiograph showing an apical lesion in teeth # 21 and 22 (b).



Sagittal and axial images confirmed a circumscribed apical lesion. Note that the apical lesion affected neither the buccal nor palatal cortical plates (C).



A CBCT scan was performed before endodontic surgery (d,e).

Ochsenbein-Luebke flap was raised to gain access and treat the apical lesion. Final size of the osteotomy (f).

MTA root-end—filled apex (g).

An immediate post-operative radiograph. No bone regeneration techniques were required (h).

The flap was repositioned and sutured tightly with 5 0 monofilament sutures (i) .

Two-yr. follow-up radiograph showing almost complete healing (j).

Figure 67: CBCT and endodontic surgery (A-j).

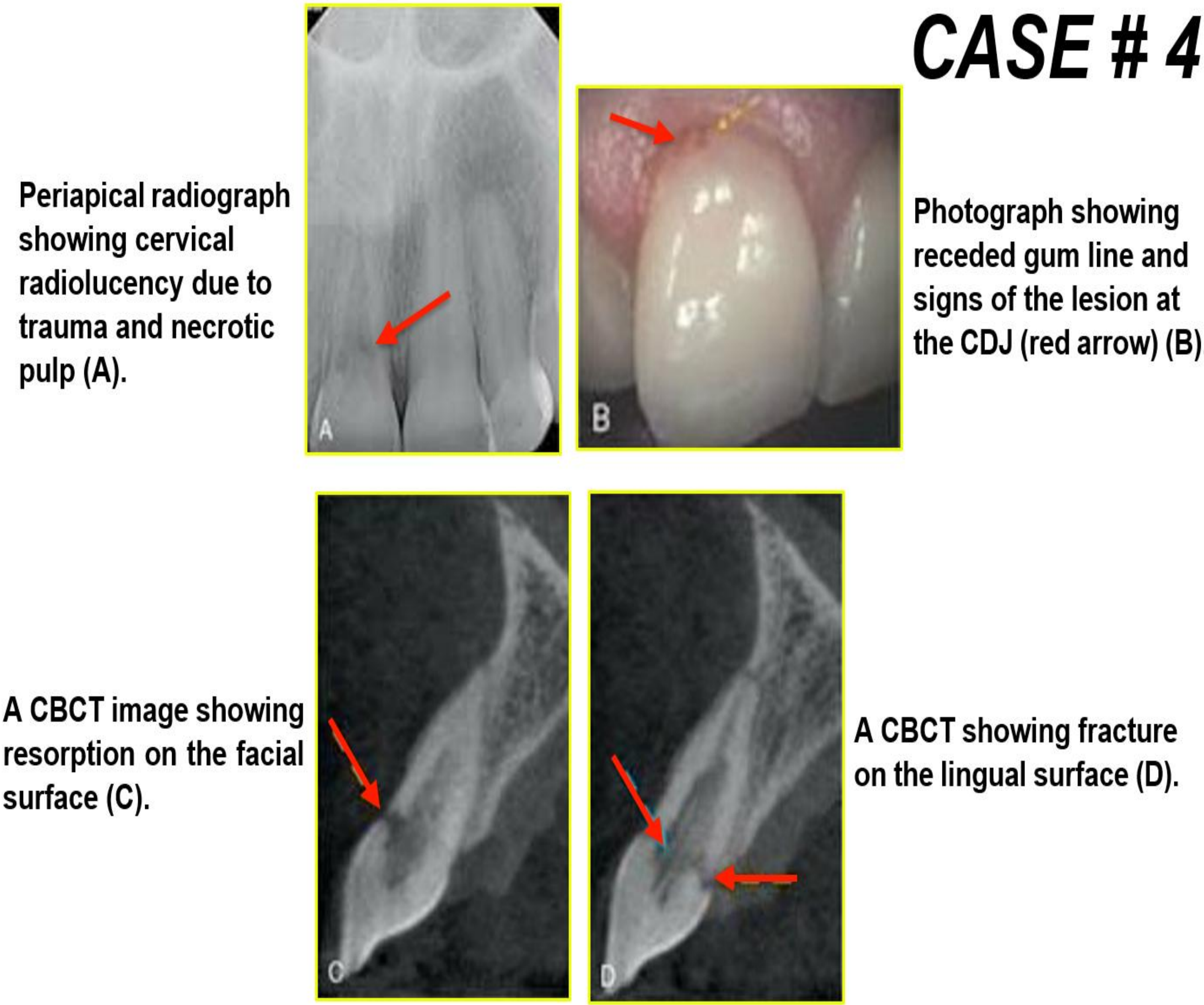
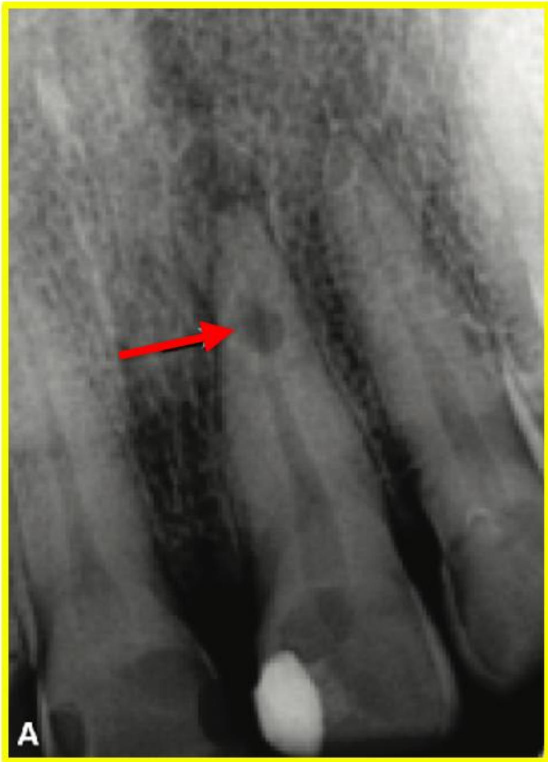
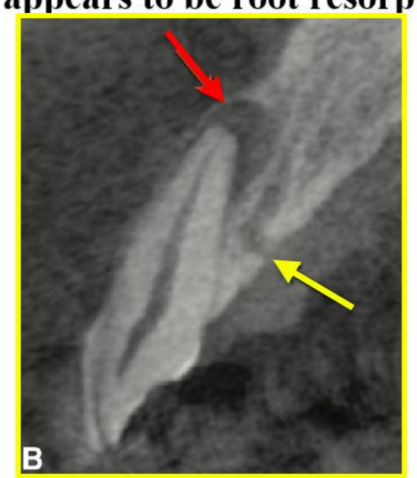


Figure 68: CBCT and external cervical resorption (A-I).

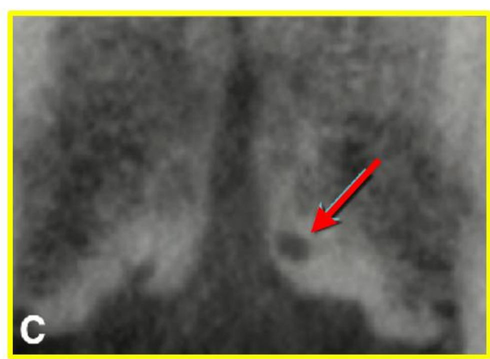
CASE # 5



A. **Periapical radiograph of a maxillary left central incisor with recurrent caries and pulpitis showing apical radiolucency, and what appears to be root resorption (red arrow).**



***B.* CBCT sagittal image showing the same tooth with an apical lesion (red arrow), without evidence of the root resorption. Instead, canalis sinuosus (yellow arrow) was detected. *Canalis Sinuosus* is a normal anatomic variation of the anterior superior alveolar neurovascular bundle with rare manifestations in the anterior maxilla.**



***C.* CBCT coronal image showing the terminal region of the *canalis sinuosus* that is distinct from the incisive canal (blue arrow). Because of the nonmidline location, *canalis sinuosus* can mimic apical lesions on conventional radiographs when superimposed on other anatomic structures, such as a tooth root in this case.**

Figure 69: CBCT used in diagnosis of canalis sinuses mimicking the appearance of root resorption (A-C).

Discussion

Radiographic evaluation supports diagnosis, treatment planning, procedural control and follow-up in endodontics. Periapical radiography remains the principal intraoral technique because it provides high spatial detail at a relatively low radiation dose. Additional projections can improve visualization of roots and canals, but the method remains limited by superimposition, absence of direct buccolingual information, projection errors and the inability of radiographic appearance alone to establish the histological nature of a periapical lesion [1-20,97,98].

Conventional film has several practical disadvantages compared with digital acquisition. These include the need for processing chemicals and dark-room facilities, susceptibility to bending and processing errors, greater demands for physical storage and retrieval and the inability to manipulate the image after processing. Anatomical superimposition also remains an intrinsic limitation of the 2D projection [1,2].

Panoramic radiography provides a useful overall survey but has lower detail than intraoral periapical or bitewing imaging for many endodontic questions. Image quality is particularly dependent on patient preparation and positioning. Radiation protection and justification of exposure are especially important in children and adolescents [1,2,16,23,99,100].

Digital intraoral systems such as RVG improve workflow through rapid acquisition, electronic storage and image processing. Their limitations include equipment cost, rigid or bulky sensors that may cause discomfort, sensor fragility, electronic artifacts and the continued absence of true three-dimensional information. Incorrect positioning or beam angulation can still produce geometric distortion and may affect measurements [1,27-30,43,101,102].

Digital subtraction radiography is particularly sensitive to small changes between serial examinations, but its value depends on accurate geometric standardization. If the two images are not closely aligned, subtraction artifacts can obscure rather than clarify change. The additional technical requirements and time needed for standardization have limited its routine clinical use [36-45,103,104].

Occlusal and bitewing radiographs have more specific roles. Occlusal images cover a larger intraoral area but provide less detail and are affected by superimposition and distortion. Bitewings are highly useful for interproximal caries and crestal bone assessment but do not provide a complete view of the root apex and may be affected by positioning errors, patient movement, discomfort and limitations in estimating the full extent of a carious lesion [19,46-61,105-108].

Three-dimensional imaging addresses several shortcomings of projection radiography by displaying volumetric anatomy. CT, MRI and CBCT, however, should not be regarded as interchangeable. CT involves ionizing radiation and may require contrast media; MRI avoids ionizing radiation and offers superior soft-tissue contrast but is less suited to highly mineralized dental tissues and may be restricted by scan time, motion, claustrophobia, cost or contraindicated implants. These factors limit routine use of both modalities for many endodontic indications [109-114].

CBCT is particularly relevant to endodontics because of its ability to display teeth and surrounding osseous structures without the superimposition inherent in 2D radiography. Nevertheless, CBCT also has limitations. High-density structures such as enamel, metallic restorations, posts and root-filling materials can generate artifacts; soft-tissue contrast is inferior to MRI and medical CT; patient movement reduces sharpness; and small cracks or hairline vertical root fractures may remain difficult to identify. CBCT also uses ionizing radiation and therefore should be selected only when the expected diagnostic benefit justifies the exposure [25,115-120].

Overall, the cases and literature considered in this investigation support a complementary rather than competitive relationship between 2D and 3D imaging. Conventional and digital intraoral radiographs remain appropriate for many routine endodontic tasks. When clinical findings and 2D imaging do not provide sufficient information, carefully selected 3D imaging can clarify anatomy or pathology and may alter treatment planning. This interpretation is consistent with published evidence showing that CBCT can reveal lesions or anatomical information not apparent on periapical radiographs, while also emphasizing that the comparative evidence base varies according to the diagnostic task [120].

Conclusion

- Periapical radiography remains a fundamental imaging method for routine endodontic diagnosis, treatment procedures and follow-up when appropriate technique and projection geometry are used
- Because periapical images are two-dimensional, superimposition and the absence of direct buccolingual information may limit assessment of complex anatomy and disease
- Panoramic radiography is useful for broad screening and anatomical overview but generally lacks the detail required for precise endodontic assessment
- Digital 2D imaging provides practical advantages over conventional film, including rapid display, electronic storage, image processing and easier communication
- RVG enables immediate digital visualization of teeth and supporting bone but retains the projection limitations of other 2D techniques
- Digital subtraction radiography can highlight small changes between standardized serial images and is useful for selected research and follow-up applications
- Occlusal radiography provides broad intraoral coverage, whereas bitewing radiography is particularly useful for interproximal caries and crestal bone assessment
- Three-dimensional imaging should be considered when the clinical examination and conventional intraoral radiographs do not provide the information required for diagnosis or treatment planning
- CT provides cross-sectional information about bone and adjacent structures but its routine endodontic role is limited
- MRI avoids ionizing radiation and is valuable for soft-tissue imaging, although its current endodontic applications remain selective
- CBCT provides volumetric visualization of teeth and surrounding structures and can be particularly valuable for complex canal anatomy, resorption, trauma, selected fractures, periapical disease and presurgical assessment
- The choice of imaging method should be based on the diagnostic question, expected clinical benefit, technical limitations and radiation-protection principles

Conflict of Interest

The author declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Ethical Statement

The project did not meet the definition of human subject research under the preview of the IRB according to federal regulations and therefore was exempt.

Informed Consent Statement

Not applicable.

Authors' Contributions

Author contributed equally to this paper.

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