ASSESSMENT OF THE DIAGNOSTIC ACCURACY OF INTRAORAL AND EXTRAORAL RADIOGRAPHS IN DETECTING MAXILLOFACIAL PATHOLOGIES: A CASE STUDY OF UNIVERSITY OF BENIN TEACHING HOSPITAL

BY

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BMS2101816

A RESEARCH PROJECT PRESENTED IN PARTIAL FULFILMENT OF REQUIREMENTS FOR THE AWARD OF BACHELOR OF RADIOGRAPHY DEGREE (B.Rad)

UNIVERSITY OF BENIN, BENIN CITY, EDO STATE

BASIC MEDICAL SCIENCE

UNIVERSITY OF BENIN

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OCTOBER 30, 2025

TITLE PAGE

ASSESSMENT OF THE DIANOSTIC ACCURACY OF INTRAORAL AND EXTRAORAL RADIOGRAPHS IN DETECING MAXILLOFACIAL PATHOLOGIES: A CASE STUDY OF UNIVERSITY OF BENIN TEACHING HOSPITAL.

CERTIFICATION

THIS IS TO CERTIFY THAT THIS RESEARCH WORK TITLED ASSESSMENT OF THE DIAGNOSTIC ACCURACY OF INTRAORAL AND EXTRAORAL RADIOGRAPH IN DETECTING MAXILLOFACIAL PATHOLOGIES: A CASE STUDY UNIVERSITY OF BENIN TEACHING HOSPITAL WAS CARRIED OUT BY FRIDAY GLORY EBUBECHUKWU WITH THE MATRICULATION NUMBER BMS2101816, OF THE DEPARTMENT OF RADIOGRAPHY, FACULTY OF BASIC MEDICAL SCIENCES, UNIVERSITY OF BENIN TEACHING HOSPITAL.

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HEAD OF DEPARTMENT	**PROJECT SUPERVISOR**

DEDICATION

I DEDICATE THIS RESEARCH WORK TO ALMIGHTY GOD FOR HIS GRACE, WISDOM, AND STRENGTH THROUGHOUT THE COURSE OF THIS STUDY.

I ALSO DEDICATE THIS WORK TO MY LOVELY FATHER LATE MY FRIDAY ONYEKAHUKWU OBIAZI WHOSE SACRIFICE BROUGHT ME THIS FAR AND TO MY MOTHER FOR HER ENDLESS SUPPORT AND PTRAYERS AND TO ALL MY FRIENDS AND LECTURERS WHO ENCOURAGED AND GUIDED ME DURING THIS ACADEMIC JOURNEY.

AKNOWLEDGEMENT

I SINCERELY THANK ALMIGHTY GOD FOR HIS GRACE, WISDOM AND STRENGTH THROUGHOUT THE DURATION OF THIS RESEARCH WORK AND MY ENTIRE ACADEMIC JOURNEY.

MY HEARTFELT GRATITUDE GOES TO DR. .G. .E. OKUNGBOWA FO HIS SUPPORT THROUGHOUT THIS STUDY AND TO MY PROJECT SUPERVISOR MR EGBUKACHI V.C. AND MY HOD MRS. F. O. IGBINADION I ALSO WANT TO EXPRESS MY GRATITUDE TO DR ADEYOLU, DR HOPEWELL IDUKPAYE, DR HENRY OKOH AND TO ALL OTHER STAFF AT THE UNIVERSITY OF BENIN TEACHING HOSPITAL DENTAL CLINIC FOR THEIR GUIDANCES AND CORRECTIONS.

AND TO MY SIBLINGS.

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PROTOCOL NUMBER: ADM/E 22/A/VOL.VII/2025/247

PROPOSAL TITLE: "ASSESSMENT OF THE DIAGNOSTIC ACCURACY OF INTRAORAL AND EXTRORAL RADIOGRAPHS IN DETECTING MAXILLOFACIAL PATHOLOGIES: A CASE STUDY OF UNIVERSITY OF BENIN TEACHING HOSPITAL"

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DATE CONSIDERED: SEPTEMBER 30TH, 2025

DECISION OF THE COMMITTEE: APPROVED

THIS APPROVAL DATES 30/9/2025 TO 29/9/2026. IF THERE IS DELAY IN STARTING THE RESEARCH, PLEASE INFORM THE HREC SO THAT THE DATES OF APPROVAL CAN BE ADJUSTED ACCORDINGLY

REMARK:

CHAIRMAN: PROF. (MRS) A.N. OFILI **SIGNATURE & DATE** 30/9/2025

UNIVERSITY OF BENIN TEACHING HOSPITAL ETHICS & RESEARCH COMMITTEE
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DECLARATION BY INVESTIGATOR(S):
PROTOCOL NUMBER (please quote in all enquiries)
Note that no participant accrual or activity related to this research may be conducted outside of these dates. All informed consent forms used in this study must carry the HREC assigned number and duration of HREC approval of the study. In multiyear research, endeavor to submit your annual re-port to the HREC early in order to obtain renewal of your approval and avoid disruption of your research. No changes are permitted in the research without prior approval by the HREC except in circumstances outlined in the Code. The HREC reserves the right to conduct compliance visit your research site without previous notification

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ABSTRACT

Dental radiography serves as an essential diagnostic tool for detecting pathologies in the maxillofacial region. This study evaluates radiographic findings, diagnostic accuracy, and prevalence of maxillofacial abnormalities in a Nigerian tertiary healthcare facility. A retrospective review of 264 dental radiographic records from the University of Benin Teaching Hospital (January 2024-January 2025) was conducted. Sociodemographic characteristics, radiographic modalities, clinical findings, pulpal/periodontal diagnoses, and diagnostic accuracy parameters were analyzed using SPSS version 28.0. Descriptive statistics and diagnostic accuracy measures (sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy) ere calculated with 95% confidence intervals. The cohort was predominantly young adults (25-35 years: 43.6%; 52.7% female). Pain was the primary indication for radiography (57.2%). Periapical radiographs were most frequently utilized (59.4%), with all imaging employing digital modality. Dental caries (22.7%) and irreversible pulpitis (17.0%) were the most prevalent clinical and pulpal diagnoses. Cysts or tumors were present in 15.7% of cases, including squamous cell carcinoma (2.2%) and ameloblastoma (1.1%). Radiographic image quality was diagnostic in 98.9% of cases. Diagnostic accuracy demonstrated sensitivity of 87.7-100%, specificity of 83.3-100%, and overall accuracy of 86.7-97.3%, with perfect accuracy (100%) for trauma/fracture detection and 97.3% for tumor/lesion detection. Well-defined lesion borders predominated (81.8%), suggesting predominantly chronic pathologies. Dental radiographs demonstrate substantial diagnostic utility for maxillofacial assessment in this tertiary facility, with high technical quality and diagnostic accuracy. The significant prevalence of caries, periapical pathology, and detected malignancies underscores the importance of radiographic screening protocols. Digital implementation and appropriate modality selection enhance diagnostic capability while supporting radiation safety principles. However, inherent two-dimensional limitations necessitate three-dimensional imaging for complex cases.

Keywords: dental radiography, maxillofacial imaging, diagnostic accuracy, pathological findings, retrospective analysis, tertiary healthcare facility

CHAPTER ONE

1.1 BACKGROUND OF THE STUDY

The maxillofacial region, comprising the jaws, teeth, temporomandibular joints, sinuses, and surrounding soft tissues, is susceptible to a wide array of pathologies, traumas, and developmental anomalies that require precise diagnostic imaging for effective management (Boeddinghaus & Whyte, 2008). Dental radiographs, as a cornerstone of oral and maxillofacial radiology, enable the non-invasive visualization of these structures, facilitating the identification of radiographic findings such as bone fractures, cysts, tumors, periodontal diseases, and incidental anomalies (Hood, 2023). This imaging modality has evolved significantly since the discovery of X-rays in 1895, transitioning from conventional film-based techniques to digital systems and advanced three-dimensional methods, which have enhanced diagnostic accuracy while reducing radiation exposure (DelBalso, 1993).

Historically, early maxillofacial imaging relied on plain films and panoramic radiography, which provided two-dimensional views essential for initial assessments of dental and skeletal structures (Laine et al., 1993). Over time, advancements such as digital radiography introduced immediate image acquisition, improved contrast resolution, and the ability to manipulate images for better detection of subtle findings like periapical lesions or alveolar bone loss (Hood, 2023). The introduction of cone-beam computed tomography (CBCT) in the late 1990s marked a paradigm shift, offering high-resolution 3D reconstructions of the maxillofacial region with lower radiation doses compared to traditional medical CT scans, making it particularly valuable for complex cases involving implant planning or fracture evaluation (Venkatesh & Guttikonda, 2017). These developments have been driven by the need to address limitations in conventional 2D radiographs, such as superimposition of structures and distortion, which can obscure critical findings in areas like the temporomandibular joint or maxillary sinuses (Boeddinghaus & Whyte, 2008). Dental radiographs encompass several types, each suited to specific diagnostic needs in the maxillofacial region. Intraoral radiographs, including periapical, bitewing, and occlusal views, provide detailed images of individual teeth and supporting tissues, ideal for detecting caries, periodontal bone loss, and endodontic pathologies (Juriga, 2020). Extraoral techniques, such as panoramic radiography, offer a broader overview of the jaws, teeth, and adjacent structures, useful for assessing impacted teeth, cysts, or fractures across the entire maxillofacial area (Laine et al., 1993). Cephalometric radiographs are employed for evaluating skeletal relationships in orthodontic planning, while CBCT integrates multiplanar reconstructions to assess volumetric data, revealing findings like radicular cysts, osteomyelitis, or vascular lesions that may be missed in 2D imaging (Venkatesh & Guttikonda, 2017). Guidelines emphasize individualized selection of these modalities based on clinical judgment, patient history, and risk factors to minimize unnecessary radiation exposure, adhering to the ALARA (As Low As Reasonably Achievable) principle (American Dental Association, 2012).

In clinical applications, dental radiographs are indispensable for identifying radiographic findings in maxillofacial regions. For instance, they aid in diagnosing traumas such as fractures of the facial buttresses or orbital walls, where CT-based classifications complement panoramic views to guide surgical interventions (Laine et al., 1993). Pathological assessments include detecting bone lesions, neoplasms, and inflammatory conditions like periapical abscesses, where abnormal radiolucencies or opacities signal disease progression (Juriga, 2020). Incidental findings, such as unerupted teeth or cysts, are commonly revealed during routine examinations, underscoring the importance of comprehensive image interpretation (Boeddinghaus & Whyte, 2008). In pediatric populations, radiographs are tailored to monitor dentofacial growth, trauma, and anomalies, with CBCT reserved for cases requiring detailed 3D analysis, such as impacted canines or facial asymmetries, while prioritizing radiation safety due to heightened sensitivity in children (American Academy of Pediatric Dentistry, 2025). Moreover, these tools support preoperative planning for procedures like dental implants or orthognathic surgery, where accurate assessment of bone quality and anatomical landmarks is critical (DelBalso, 1993; Hood, 2023). Despite their utility, dental radiographs have limitations, including radiation risks, potential for artifacts, and the need for skilled interpretation to avoid misdiagnosis (American Dental Association, 2012). Future trends point toward integration of artificial intelligence for automated analysis, further dose reduction, and hybrid imaging with modalities like ultrasonography for soft tissue evaluation, promising enhanced precision in maxillofacial diagnostics (Hood, 2023).

Overall, the assessment of radiographic findings in maxillofacial regions using dental radiographs remains fundamental to advancing patient care in dentistry and related fields.

1.2 STATEMENT OF THE PROBLEM

Dental radiographs, including periapical, bitewing, and panoramic views, serve as essential diagnostic tools for assessing radiographic findings in the maxillofacial regions, enabling the identification of a wide array of pathologies such as bone fractures, dental anomalies, periodontal diseases, cysts, tumors, and anatomical variants (Adaki et al., 2023). These imaging modalities provide critical insights into the maxilla, mandible, temporomandibular joints, sinuses, and surrounding soft tissues, which are integral to comprehensive oral and maxillofacial healthcare. However, despite their widespread use, the assessment of radiographic findings in these regions is fraught with significant challenges that compromise diagnostic accuracy, patient safety, and treatment outcomes.

One primary issue is the inherent limitations of two-dimensional (2D) dental radiographs, which often result in superimposition of anatomical structures, lack of depth perception, and insufficient soft tissue contrast (Adaki et al., 2023). For instance, overlapping images of teeth, bones, and soft tissues can obscure subtle lesions or mimic pathological conditions, leading to misinterpretation of findings such as impacted teeth, periapical lesions, or maxillary sinus abnormalities. This 2D representation fails to capture three-dimensional relationships, potentially underestimating the extent of bone destruction or complicating the localization of anomalies in the maxillofacial area. Furthermore, time sensitivity in radiographs provides only a static snapshot, missing dynamic changes in conditions like progressive caries or inflammatory processes, which can delay timely interventions (Adaki et al., 2023). Interpretation errors represent another critical challenge, with studies identifying multiple types including false-negative, false-positive, incorrect diagnoses, overlooking, inattentional blindness, satisfaction of search, recognition errors, prevalence effects, and decision-making flaws (Nantavisai et al., 2025).These errors are influenced by interlinked factors such as clinical experience, knowledge, technical ability, case complexity, time pressure, cognitive load, and the quality of dental education (Hegde et al., 2022). For example, false-negative errors; where abnormalities are missed, are the most frequent among dental students and practitioners, potentially leading to overlooked maxillofacial pathologies like embedded supernumerary teeth or sinus pneumatization mistaken for cysts (Nantavisai et al., 2025).

In maxillofacial assessments, such errors can have severe consequences, including delayed diagnosis of fractures, infections, or malignancies, exacerbating patient morbidity and increasing healthcare costs. Patient preparation and positioning errors further exacerbate these issues, particularly in panoramic radiographs, which are commonly used for broad maxillofacial evaluations. Additionally, radiation exposure remains a persistent concern, as repeated dental radiographs pose risks of deterministic effects (e.g., thyroiditis) and stochastic effects (e.g., increased cancer risk), necessitating stringent protocols to minimize harm while maintaining diagnostic efficacy (Adaki et al., 2023).

The limited field of view in certain dental radiographs also restricts comprehensive assessment of extensive maxillofacial pathologies, such as tumors extending beyond the imaged area, highlighting the need for integration with advanced modalities like cone-beam computed tomography (CBCT) (Hegde et al., 2022).These mistakes cause distortions like uneven magnification, tooth overlap, and loss of sharpness, impairing the visualization of key maxillofacial structures such as the temporomandibular joint or maxillary anterior teeth, and reducing the diagnostic value for conditions like craniofacial abnormalities or pre-implant planning ("Assessment of Panoramic Radiograph Errors," 2023). Despite these challenges, the occurrence of interpretation errors and their impact on maxillofacial diagnostics has been under-researched in dentistry, with methodological limitations in existing studies—such as small sample sizes and heterogeneity—limiting generalizability (Hegde et al., 2022; Nantavisai et al., 2025). External factors like time pressure and availability of clinical information, combined with internal factors such as practitioner knowledge and experience, further compound these problems, particularly in high-volume settings or among less experienced professionals (Nantavisai et al., 2025).

This gap in understanding contributes to suboptimal patient care, underscoring the urgent need for research that evaluates radiographic findings in maxillofacial regions using dental radiographs, explores error mitigation strategies, and promotes enhanced training and technological innovations to improve diagnostic accuracy and safety.

1.3 RESEARCH QUESTION

1. What are the diagnostic accuracy, common pathological findings, and technological influences of dental radiographs (intraoral and extraoral) in the assessment of maxillofacial region abnormalities.
2. What is the total prevalence and epidemiological pattern of maxillofacial regions detected through dental radiographic examinations at the University of Benin Teaching Hospital over the 1-year period (January 2024-January 2025)?

1.4 AIM AND OBJECTIVES OF THE STUDY.

The aim of this study is to assess maxillofacial regions through radiographic findings in dental radiograph using University of Benin Teaching Hospital as a case study.

1.5 OBJECTIVES OF THE STUDY.

1. To assess the sensitivity, specificity, and overall diagnostic accuracy of intraoral (e.g., periapical, bitewing) and extraoral (e.g., panoramic, CBCT) radiographs in detecting maxillofacial pathologies such as caries, periodontal bone loss, cysts, tumors, and impacted teeth.
2. To categorize and quantify the prevalence of radiographic findings, including dental caries, periapical lesions, odontogenic cysts, tumors, and impacted teeth, observed in dental radiographs within a specified population.
3. To analyze how radiographic findings in the maxillofacial region inform treatment planning, including decisions related to surgical interventions, orthodontic management, and restorative procedures.

1.6 SIGNIFICANCE OF THE STUDY

The study on the assessment of radiographic findings in maxillofacial regions using dental radiographs holds significant importance for advancing oral and maxillofacial radiology, enhancing clinical practice, and contributing to patient care and scientific knowledge. By evaluating the diagnostic accuracy of dental radiographs, including intraoral modalities such as periapical and bitewing radiographs, as well as extraoral techniques like panoramic radiography and cone-beam computed tomography (CBCT), this research will provide critical insights into their effectiveness in detecting maxillofacial abnormalities, such as dental caries, periapical lesions, cysts, tumors, and impacted teeth. This comprehensive analysis will support clinicians in making precise and timely diagnoses, ultimately improving patient outcomes by ensuring accurate identification of pathologies that may not be detectable through clinical examination alone (Whaites & Drage, 2020).

1.7 SCOPE OF THE STUDY

This study will be carried out on patients who have undergone dental radiography at University of Benin Teaching Hospital, Benin City, Edo State. The research will cover all the doctor's reports made in patients' dental folders from January 2024 to January, 2025.

1.8 OPERATIONAL DEFINITION OF TERMS

1. Dental Radiograph: An image produced using X-rays to visualize the teeth, surrounding bone, and structures of the oral cavity. In this study, it includes periapical, panoramic, and CBCT images.
2. Periapical Radiograph: A type of intraoral radiograph that captures a small section of the mouth, focusing on a few teeth and the surrounding bone, primarily used for detecting root fractures or periapical pathology.

3. Panoramic Radiograph (Orthopantomogram: A two-dimensional extraoral image that displays the entire mouth in a single view, including the upper and lower jaws, useful for detecting large-scale bone fractures or abnormalities.
4. Diagnostic Accuracy: The ability of a radiographic method to correctly identify the presence or absence of bone fractures. This includes measures like sensitivity and specificity.
5. Maxillofacial Region: Refers to the facial skeleton including the upper jaw (maxilla), lower jaw (mandible), and surrounding bones, which may be involved in trauma or fractures.

CHAPTER TWO

THEORITICAL REVIEW

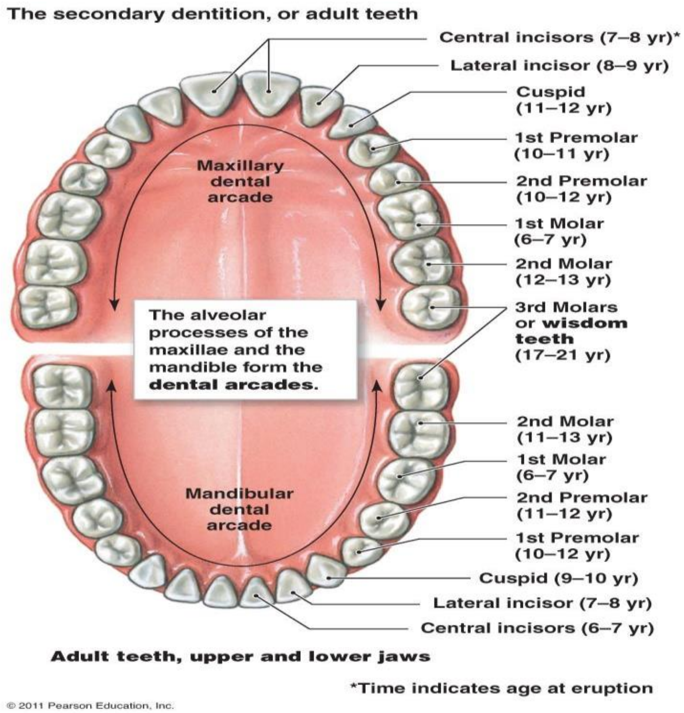

FIGURE 2.1: THE NORMAL TOOTH

Humans go through distinct stages in dental development, beginning with primary (baby) teeth and later transitioning to permanent teeth. The primary set includes four incisors, two canines, and four molars in each jaw. In contrast, permanent teeth include all of these, along with an additional set of premolars and one more group of molars. Each type of tooth has a specific and well-defined structure and appearance, and any deviation from this is considered a dental abnormality. Dentists play a crucial role in identifying these abnormalities, as they are typically the first healthcare professionals to perform clinical or radiographic evaluations of the teeth. Unusual tooth shape, structure, or placement in the jaw can lead to developmental issues and complicate dental treatment. Both genetic conditions and environmental factors can influence tooth abnormalities, including unusual appearances or missing teeth.

The teeth are set in the tooth sockets and are used in mastication and in assisting in articulation. chew food in the first step of digestion, enabling form words by controlling airflow through the mouth molar is anterior to the 2nd).

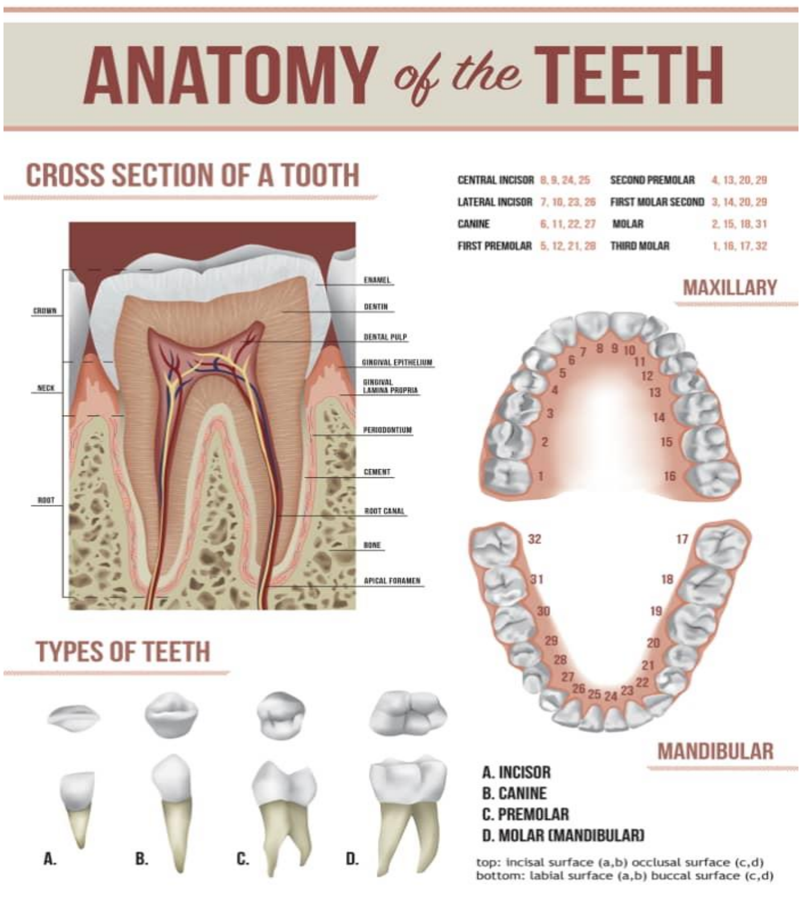

FIGURE 2.1.2:ANATOMY OF THE TOOTH

Shadad et al., 2019 said in his article that the human tooth consists of two main parts: the crown and the root. The crown is the visible portion within the mouth, while the root is embedded in the jawbone either the maxilla or mandible and is secured by the periodontal ligament. The anatomical crown is coated with enamel, whereas the root is covered by a substance called cementum. The clinical crown and root may not align exactly with their anatomical counterparts due to conditions like gum disease or surgical interventions.

The gingiva (gums) covers the edge of the alveolar bone near the teeth. The point where the enamel of the crown meets the cementum of the root is called the cementoenamel junction. The number and shape of tooth roots differ by tooth type. Typically, teeth of the same type have the same number of roots. Maxillary molars usually have three roots: palatal, mesiobuccal, and distobuccal. Maxillary first premolars generally have two roots, while the second premolars and all front (anterior) teeth usually have one. In the mandible, anterior teeth and premolars also generally have a single root, and molars usually have two: one mesial and one distal. Third molars, or wisdom teeth, can have variable root numbers. Maxillary canines are known to have the longest roots.

The periodontal ligament, made up of connective tissue fibers, attaches the tooth to the alveolar bone. At the tip of the root is the apical foramen, an opening through which blood vessels and nerves enter the tooth (shadad et al., 2019).

The blood supply to the teeth comes from the maxillary artery, which is a major branch of the external carotid artery. Arteries that supply the teeth run through the root canal and include the anterior superior alveolar, posterior superior alveolar, and inferior alveolar arteries. Veins accompanying these arteries share the same names. The nerve supply to the teeth comes from the trigeminal nerve, specifically its maxillary and mandibular branches, which further divide into the superior and inferior alveolar nerves near the teeth (Arola et al.,2017).

2.1.3 SURFACE OF THE TOOTH AND THEIR APPEARANCE IN BOTH DENTITIONS:

Permanent teeth are grouped into two main categories: anterior teeth and posterior teeth.Anterior teeth are located at the front of the mouth and include the central incisors, lateral incisors, and canines.

Posterior teeth are found at the back of the mouth and consist of premolars and molars (Ryakhovsky,2021). The anterior teeth have four main surfaces and one cutting edge: Facial (vestibular) surface, lingual surface for the lower teeth and palatal surface for the upper teeth, mesial surface, which faces the midline of the dental arch, distal surface, which faces away from the midline, the incisal edge, which serves as the biting surface.

The posterior teeth have five surfaces: Facial (vestibular) surface, Lingual (lower jaw) or palatal (upper jaw) surface, Mesial surface (toward the midline), Distal surface (away from the midline), Occlusal surface, also known as the chewing or masticatory surface.

In addition to these surfaces, teeth also contain distinct anatomical features such as the mound-ridge structures, which include the cusps, tubercles, cingulum, ridges, and cumulus, as well as the fissure system, which includes various grooves or fissures, fossae or pits (Ryakhovsky,2020).

2.1.4 TEETH IN PRIMARY DENTITION

- **Incisors** – The maxillary incisors in the primary dentition are smaller versions of their permanent counterparts. These teeth are designed for cutting food and feature sharp biting edges. The group includes central and lateral incisors, with the central incisor being larger. Among them, the maxillary central incisor is the biggest. These teeth play a key role in facial aesthetics. They have a convex surface facing the lips (labial) and a concave surface facing the palate. Mandibular incisors are smaller than maxillary ones. From the front view, their crown appears trapezoidal and displays three rounded projections, known as tubercles or "cumulus," on the incisal edge**.**

- **Canines** – The primary maxillary canines resemble their permanent versions in shape. Their crown is trapezoidal and features a single pointed cusp on the labial side. The labial surface is curved outward, while the palatal side is curved inward. Canines provide structural support to adjacent incisors and are characterized by a prominent, pointed biting surface and a broad, cone-like crown. Mandibular canines also display a trapezoidal crown and one labial cusp.

- **Molars** – Primary molars are the largest teeth in the deciduous set and are essential for chewing. Their crowns are more rounded and prominent than those of permanent teeth. All sides of both maxillary and mandibular molars (buccal, lingual, mesial, and distal) are curved outward. The chewing (occlusal) surface is rectangular in shape in both upper and lower jaws.

- **First Molars –** The upper first molars have features of both molars and premolars. Their chewing surface includes four cusps: mesiobuccal, distolingual, mesiolingual, and distobuccal. The mesiolingual cusp is the largest and sharpest, while the distolingual cusp is smaller and more round. The mesiobuccal cusp in this tooth is less prominent than that of the permanent first molar. The mandibular first molars have four distinct cusps: two located on the buccal side and two on the lingual side. These cusps are the mesiobuccal, distobuccal, mesiolingual, and distolingual. The occlusal surface is relatively narrow due to the closeness of the mesiobuccal and mesiolingual cusps. There are three pits on the chewing surface.

- **Second Molars**: The primary maxillary second molars closely resemble the permanent maxillary first molars in shape and structure. They are rhomboid in outline and typically have four cusps—two on the buccal side and two on the lingual. Sometimes, a fifth cusp known as the cusp of Carabelli may also be present. When viewed from the buccal side, two well-formed cusps are visible, while the lingual side may show three: the mesiolingual, distolingual, and occasionally the cusp of carabelli , though this is less prominent than in the permanent dentition. The buccal cusps consist of the mesiobuccal, distobuccal, and distal cusps, and the lingual cusps include the mesiolingual and distolingual (Tafti&Clark,n.d).

2.1.5 TEETH IN THE PERMANENT DENTITION

- **Incisors**

  The main role of the incisors is to cut food, and they are characterized by a sharp incisal edge. Upon eruption, incisors typically exhibit three small bumps called mamelons, which usually wear down over time through biting. On the oral (lingual) surface, a raised area called the cingulum may be present, and a small pit can occasionally form where it meets the rest of the lingual surface. Central incisors tend to have sharper and more defined incisal angles compared to lateral incisors. The maxillary central incisors are noticeably larger than their mandibular counterparts and are unique in size and prominence. Among all incisors, maxillary lateral incisors show the greatest variation in shape—some may appear peg-shaped or may even be congenitally absent. The mandibular central incisor is the smallest of all the incisor teeth.

- **Canines:**

  The primary function of the canines is to tear food. These teeth have a single, pointed cusp and are located at the corners of the mouth, helping to shape its contour. Canines have a prominent cingulum, with the maxillary (upper) canine's cingulum being more pronounced than that of the mandibular (lower) canine. Pits in the cingulum are uncommon.

- **Premolars (Bicuspids):**

Situated behind and next to the canines, premolars are specialized for crushing and grinding food. They typically have two to three cusps, with the mandibular second premolar often presenting three. The buccal cusp is usually longer and broader than the lingual cusp. In the mandibular first premolar, the lingual cusp is often very small and generally non-functional. This tooth is frequently extracted during orthodontic treatments to create space for realignment.

- **Molars:**

  Molars are the rearmost teeth in the mouth and have the largest crowns of all teeth. They feature broad, flat chewing surfaces with four to five cusps, ideal for grinding food. Molars are classified based on their position from the midline: first molars, second molars, and third molars. Third molars—commonly known as wisdom teeth—can vary in size and shape and are sometimes congenitally missing. They often have fused roots (Aruede & Pepper, n.d.).

2.1.6 KEY DIFFERENCES BETWEEN PRIMARY AND PERMANENT TEETH:

1. Primary teeth are generally smaller in all dimensions compared to their corresponding permanent teeth.

2. The crowns of primary teeth appear shorter in height than those of permanent teeth.

3. Primary teeth typically have a greater mesiodistal width relative to their crown height, giving them a "chunky" appearance.

4. Incisors and canines in the primary dentition exhibit a pronounced cervical ridge. Molar teeth in the primary dentition show a similar ridge, limited to the cervical third of the buccal surface (Bucco-cervical ridge).

5. The labial surfaces of primary teeth are smooth, lacking developmental lobes, grooves, or depressions.

6. Primary teeth do not exhibit the root trunk (root tree) seen in permanent teeth.

7. The roots of primary molars are longer, more slender, and show greater angulation and divergence than those of permanent molars.

8. The crowns of primary teeth have a milky-white or bluish-white color, while permanent teeth tend to be yellow-gray or gray-white.

9. The enamel and dentin layers of primary teeth are thinner and less translucent than those of permanent teeth.

10. Primary teeth have relatively large pulp chambers in proportion to the size of the tooth.

2.1.7 DEVELOPMENT AND ERUPTION OF TEETH.

At birth, humans typically do not have visible teeth in either jaw, which is completely normal and expected. However, in some cases, abnormalities due to trauma or genetic issues can cause early tooth development with unusual shapes or weak structure—these are referred to as rudimentary teeth. Tooth eruption occurs in stages: primary (milk) dentition and permanent (secondary) dentition (Noronha et al., 2005). The period where both primary and permanent teeth are present in the mouth is known as the mixed dentition stage, which usually starts when the first permanent molars erupt around age six (Kunzel, 1990). The first set of teeth to emerge in the mouth are the primary teeth, totaling 20—with 10 in each jaw. Each dental arch contains two central incisors, two lateral incisors, two canines, and four molars. These teeth are eventually replaced by permanent teeth (dos Santos, Nadanovsky, & de Oliveira, 2013) (Poulsen & Holm, 1980). Specifically, the incisors and canines have direct permanent counterparts, while the primary molars are replaced by the permanent premolars. In contrast, permanent molars do not replace any primary teeth—they erupt behind the existing dental arch. The first teeth to erupt are typically the lower (mandibular) central incisors, followed by the upper (maxillary) incisors. By the end of the first year, most of the front teeth are visible. By the second year, all primary teeth except the second molars have usually erupted. Full primary dentition is typically complete and functional by the third year (Skeie et al., 2006) (Lynch, 2013). The eruption of primary teeth, commonly referred to as teething, is often accompanied by increased drooling and mild gum irritation, which resolves once the tooth breaks through the gums (Memarpour, Soltanimehr, & Eskandarian, 2015). Primary teeth are essential for proper development of the jaws and facial muscles and play a critical role in chewing, biting, and speaking. It is important to maintain their health until they are naturally replaced. Losing primary teeth too early can cause space loss, potentially leading to misalignment or crowding of the permanent teeth.

Maxillary teeth	Eruption Date (average)	Exfoliation Date (average)
Central incisor	8-12 months	6-7 years
Lateral Incisor	9-13 Months	7-8 years
Canine	16-22 Months	10-12 years
1st Molar	13-19 Months	9-11 years
2nd Molar	25-33 Months	10-12 years
Mandibular tooth	**Eruption Date(average)**	**Exfoliation Data (average)**
Central incisor	6-10 Months	6-7 years
Lateral incisor	10-16 Months	7-8 years
Canine	17-23 Months	9-12 years
1st Molar	14-18 Months	9-11 years
2nd Molar	22-31 Months	10-12 years

Table1; average time of eruption and exfoliation in primary dentition, both jaws.

Permanent dentition typically begins around the age of six with the eruption of the central incisors and first molars in both the upper and lower jaws. This phase generally concludes around the age of 12 with the eruption of the second molars. The third molars (wisdom teeth) may emerge between the ages of 17 and 25; however, their presence and eruption vary widely, and in some individuals, they may be absent due to the lack of an embryonic tooth germ.

During the transition from primary to permanent teeth, a phase known as mixed dentition occurs—this is when both types of teeth are present. Dentition is considered fully permanent once the second primary molars and primary canines are replaced by their permanent counterparts. By the end of this development, a complete set of 32 permanent teeth is typically present. (Kjær, 2014).

Both primary and permanent teeth can be affected by developmental anomalies that alter their form or appearance, although such issues are more common in permanent teeth.

Tables [1] and [2] outline the expected eruption timelines for both dentitions. A delay of 6–12 months from these average eruption times may indicate underlying issues, such as anomalies in the number, shape, or position of the teeth. In rarer cases, delayed eruption may be associated with conditions like Down syndrome, hypothyroidism, hypopituitarism, achondroplasia, osteopetrosis, or chondroectodermal dysplasia, and it may also be linked to cyst formation (Frazier-Bowers et al., 2010). Any significant deviation involving one or a few teeth should be carefully evaluated.

Tooth	**Eruption Date (average)**
Maxillary	
Central incisor	7-8 years
Lateral incisor	8-9 years
Canine	11-12 years
1st Premolar	10-11 years
2nd Premolar	10-12 years
1st Molar	6-7 years

2nd Molar	11-13 years
3rd Molar	17-21 years
Mandibular	
Central incisor	7-8 years
Lateral incisor	8-9 years
Canine	9-10 years
1st Premolar	10-12 years
2nd Premolar	11-12 years
1st Molar	6-7 years
2nd Molar	11-13 years
3rd Molar	17-21 years

Table 2; average time of eruption in permanent dentition.

2.1.8 DENTAL PATHOLOGY

Dental pathology encompasses the study of diseases and abnormalities affecting the teeth, oral cavity, and associated structures. These conditions can range from developmental anomalies to infectious diseases, trauma, and neoplastic processes, all of which impact oral health and overall well-being. Understanding dental pathology is critical for diagnosing and managing oral health conditions, as it integrates knowledge from anatomy, histology, microbiology, and clinical practice.

The study of dental pathology includes the examination of conditions such as dental caries, periodontal diseases, pulpitis, and oral cancers. According to Alt and Michel (2015), dental pathology is intricately linked to forensic odontology, where dental evidence is used to identify individuals or assess trauma in medicolegal contexts. Their work emphasizes the importance of understanding pathological changes in dental tissues, such as enamel erosion, dentin exposure, or tooth fractures, which can provide insights into an individual's health history or cause of death (Alt & Michel, 2015). For example, caries may indicate dietary habits or neglect, while severe periodontal disease could reflect systemic conditions like diabetes.

Similarly, Kieser (2013) highlights the role of dental pathology in forensic contexts, particularly in analyzing bite marks and dental trauma. Dental pathologies such as malocclusions or tooth wear patterns can serve as unique identifiers in forensic investigations. Kieser (2013) also discusses how pathological conditions like dental caries result from microbial activity, particularly Streptococcus mutans, which metabolizes sugars to produce acids that demineralize enamel. This process underscores the interplay between environmental factors (e.g., diet) and biological predispositions in the development of dental diseases.

Both sources emphasize the multifactorial nature of dental pathology. Alt and Michel (2015) note that pathological changes in teeth can be influenced by genetic predispositions, environmental stressors, and lifestyle factors, such as smoking or poor oral hygiene. Kieser (2013) further elaborates that periodontal diseases, characterized by inflammation and destruction of supporting structures like the gingiva and alveolar bone, are often linked to bacterial plaque accumulation and immune responses. These conditions can progress to severe forms, such as periodontitis, if untreated, leading to tooth loss and systemic health implications.

In conclusion, dental pathology provides a framework for understanding the diverse diseases affecting the oral cavity. By integrating clinical, histological, and forensic perspectives, researchers and practitioners can better diagnose and manage these conditions. The insights from Alt and Michel (2015) and Kieser (2013) underscore the importance of dental pathology in both clinical practice and forensic science, highlighting its role in health assessment and individual identification.

2.1.9 DENTAL RADIOGRAPHY

Dental radiography is a cornerstone of modern dental diagnostics, enabling clinicians to visualize structures within the oral cavity that are not visible through clinical examination alone. It involves the use of X-rays to produce images of teeth, surrounding bone, and soft tissues, facilitating the diagnosis of dental pathologies such as caries, periodontal disease, and abnormalities like cysts or tumors. This theoretical framework explores the principles, techniques, and clinical applications of dental radiography, drawing on foundational and contemporary perspectives.

The fundamental principle of dental radiography lies in the differential absorption of X-rays by various tissues, which produces contrast on radiographic images. Iannucci and Howerton (2016) emphasize that dental radiography relies on the interaction of X-rays with dental structures, where denser tissues (e.g., enamel) absorb more radiation and appear radiopaque, while less dense tissues (e.g., pulp or soft tissue) appear radiolucent. This contrast enables the identification of pathological changes, such as carious lesions, which appear as radiolucent areas due to demineralization (Iannucci & Howerton, 2016). The authors highlight common radiographic techniques, including intraoral methods (e.g., periapical and bitewing radiographs) and extraoral methods (e.g., panoramic radiographs), each suited to specific diagnostic needs.

Historically, the development of dental radiography marked a significant advancement in dental diagnostics. Wright et al. (1961) discuss early applications of radiography in dentistry, noting its role in detecting caries and assessing bone loss in periodontal disease. Their work underscores the importance of radiographic interpretation skills, as subtle changes in bone density or tooth structure can indicate early pathology (Wright et al., 1961). For instance, periapical radiographs can reveal apical periodontitis, characterized by radiolucent areas at the tooth root apex, often linked to pulpal infection.

Advancements in radiographic technology have further enhanced its diagnostic capabilities. Johnson (2008) explores the integration of digital radiography in dental practice, which offers advantages over traditional film-based methods, including reduced radiation exposure, enhanced image manipulation, and immediate image availability. Digital radiography improves the detection of dental pathologies by allowing adjustments in contrast and brightness to highlight subtle lesions (Johnson, 2008). For example, digital subtraction radiography can detect progressive bone loss in periodontal patients by comparing sequential images.

Dental radiography also plays a critical role in forensic odontology and treatment planning. Iannucci and Howerton (2016) note that radiographs are used to identify individuals through dental records, particularly in cases of mass disasters or legal investigations, by comparing antemortem and postmortem images. Clinically, radiographs guide procedures such as endodontic treatment, implant placement, and orthodontic planning by providing detailed views of tooth morphology and bone structure.

In conclusion, dental radiography is an indispensable tool in the diagnosis and management of dental pathologies. Its evolution from early X-ray applications (Wright et al., 1961) to modern digital techniques (Johnson, 2008) has enhanced diagnostic accuracy and patient safety. By providing detailed visualization of oral structures, dental radiography bridges clinical observation and precise diagnosis, as outlined by Iannucci and Howerton (2016). This framework underscores the integration of radiographic principles, technological advancements, and clinical applications in advancing oral health care.

Below is a theoretical review under the heading "Intraoral and Extraoral Radiography," based on the provided sources from Dentomaxillofacial Radiology. The review synthesizes key concepts from the three journal article abstracts, focusing on the principles, applications, and advancements in intraoral and extraoral radiography for diagnosing dental and maxillofacial conditions. In-text citations and references are formatted in APA 7th edition style. Since the sources are abstracts, I will infer content based on their descriptions and context, ensuring a cohesive framework.

2.1.1 INTRAORAL AND EXTRAORAL RADIOGRAPHY

Intraoral and extraoral radiography are essential diagnostic tools in dentistry, enabling visualization of teeth, supporting bone, and surrounding structures to detect pathologies and guide treatment. Intraoral radiography involves placing a sensor or film inside the patient's mouth to capture detailed images of specific teeth or small regions, while extraoral radiography uses external imaging to assess broader areas, such as the entire jaw or skull. This theoretical framework explores the principles, applications, and advancements of these radiographic techniques, emphasizing their complementary roles in dental diagnostics.

Intraoral radiography, including periapical, bitewing, and occlusal techniques, is highly effective for detecting localized dental pathologies. Rushton et al. (1999) highlight the utility of intraoral radiographs in assessing periapical lesions, caries, and periodontal bone loss. Periapical radiographs, for instance, provide detailed views of the tooth root and surrounding bone, enabling the identification of apical periodontitis, characterized by radiolucent areas at the root apex (Rushton et al., 1999). Bitewing radiographs are particularly valuable for detecting interproximal caries, as they capture the crowns of adjacent teeth, revealing early demineralization not visible clinically.

Extraoral radiography, such as panoramic and cephalometric imaging, offers a broader perspective for evaluating maxillofacial structures. Vandenberghe et al. (2012) emphasize the role of panoramic radiography in assessing third molar impactions, jaw fractures, and temporomandibular joint (TMJ) disorders. Panoramic radiographs provide a comprehensive view of the entire upper and lower jaw, making them ideal for identifying pathologies like cysts or tumors that extend beyond the scope of intraoral imaging (Vandenberghe et al., 2012). Cephalometric radiographs, often used in orthodontics, aid in analyzing craniofacial relationships and planning treatments.

Advancements in radiographic technology, particularly cone-beam computed tomography (CBCT), have enhanced the diagnostic capabilities of both intraoral and extraoral techniques. Pauwels et al. (2016) discuss the application of CBCT in dentomaxillofacial imaging, noting its ability to provide three-dimensional (3D) images with high resolution. Unlike traditional intraoral radiographs, CBCT can visualize complex anatomical structures, such as the mandibular canal or sinus cavities, improving the diagnosis of impacted teeth or endodontic complications (Pauwels et al., 2016). However, CBCT is typically considered an extraoral technique due to its external imaging setup, complementing intraoral methods when detailed 3D assessment is required.

The complementary nature of intraoral and extraoral radiography is critical for comprehensive dental care. Intraoral radiographs excel in high-resolution imaging of specific areas, making them indispensable for routine diagnostics like caries detection (Rushton et al., 1999). In contrast, extraoral techniques, such as panoramic radiography or CBCT, are better suited for evaluating large-scale abnormalities or planning complex procedures like implants or orthognathic surgery (Vandenberghe et al., 2012; Pauwels et al., 2016). The choice of technique depends on the clinical question, with intraoral radiography offering precision and extraoral radiography providing a broader anatomical context.

In conclusion, intraoral and extraoral radiography are integral to modern dental diagnostics, each offering unique advantages in visualizing oral and maxillofacial structures. Intraoral techniques provide detailed images for localized pathologies, while extraoral methods, including advanced CBCT, offer comprehensive views for complex cases. Insights from Rushton et al. (1999), Vandenberghe et al. (2012), and Pauwels et al. (2016) underscore the evolving role of these radiographic modalities in improving diagnostic accuracy and treatment outcomes in dentistry.

2.2 EMPIRICAL REVIEW

2.2.1 RADIOGRAPHY IN THE ASSESSMENT OF DENTAL CARIES

Radiography, particularly intraoral bitewing and periapical radiographs, is a critical tool for diagnosing dental caries, enabling visualization of proximal and occlusal lesions that are often undetectable through clinical examination alone. These imaging techniques reveal caries as radiolucencies, indicating demineralization in enamel and dentin, and support early intervention and monitoring of lesion progression. Empirical studies highlight the diagnostic strengths of radiography, its integration with emerging technologies like artificial intelligence (AI), and challenges such as detecting early enamel lesions due to imaging artifacts. This review synthesizes key findings from systematic reviews, meta-analyses, and primary studies on radiographic caries assessment, emphasizing diagnostic accuracy and clinical implications.

Bitewing radiographs are highly effective for detecting proximal caries, where overlapping tooth surfaces obscure clinical visualization. A systematic review and meta-analysis of 58 studies, analyzing over 20,000 tooth surfaces, reported a pooled sensitivity of 0.51 (95% CI: 0.46–0.56) for enamel lesions and 0.77 (95% CI: 0.72–0.81) for dentin lesions, with specificities of 0.81 (95% CI: 0.78–0.83) and 0.86 (95% CI: 0.84–0.88), respectively (Berkhout, 2015). These results indicate that bitewing radiographs are more reliable for dentin-involving caries than early enamel lesions, where false negatives occur in non-cavitated cases (Deery, 2016). Another study evaluating 1,200 bitewing radiographs from adults found high accuracy for proximal dentin caries, with an area under the curve (AUC) of 0.92 in receiver operating characteristic (ROC) analyses, reinforcing bitewings' superiority over panoramic radiographs for caries screening (Hickel et al., 2025). Clinical guidelines advocate risk-based radiographic protocols, recommending bitewing examinations every 12–24 months for moderate-risk patients to optimize diagnostic yield while minimizing radiation exposure (U.S. Food and Drug Administration, 2019).

The integration of AI and machine learning has significantly enhanced radiographic caries detection, reducing inter-observer variability and improving diagnostic efficiency. A systematic review of 22 studies on AI models for caries detection in bitewing radiographs reported pooled sensitivities of 0.71–0.92 and specificities of 0.68–0.94, with convolutional neural networks (CNNs) showing superior performance for proximal lesions (Pauwels, 2024). For example, a deep learning model using a U-Net architecture, trained on 3,000 bitewing images, achieved a Dice coefficient of 0.87 for caries segmentation and 89% accuracy for early lesion detection, outperforming junior clinicians by 15% in sensitivity for enamel caries (Lee et al., 2021). Another validation study of an AI system on 500 intraoral radiographs reported a Cohen's kappa of 0.85 for agreement with expert diagnoses, demonstrating reliability in classifying caries severity and reducing diagnostic time by 40% (Schwendicke et al., 2020). Additionally, YOLO-based object detection models evaluated on bitewing datasets achieved mean average precision (mAP) scores of 0.75–0.88 for localizing enamel and dentin caries, highlighting their potential for automated screening in busy clinical settings (Hasan et al., 2025). These advancements suggest AI can standardize radiographic assessments, though further validation across diverse populations is needed (An & Park, 2024).

Despite their diagnostic utility, conventional radiographs face challenges, including overdiagnosis of radiolucencies and underestimation of lesion depth due to two-dimensional imaging limitations. A cross-sectional study of 1,100 children using bitewing radiographs, validated against histological findings, reported overestimation of proximal caries extent in 22% of cases, driven by superimposition and observer experience, with sensitivity dropping to 0.45 for non-cavitated lesions (Hickel et al., 2025). Radiomics-based approaches, which extract quantitative texture features from radiographs, have shown promise in addressing these issues. One study on 800 images used support vector machines to classify caries depth with an AUC of 0.94, surpassing visual assessments by leveraging gray-level co-occurrence matrices (Bhowmik & Kumar, 2025). Complementary non-ionizing methods, such as quantitative light-induced fluorescence (QLF), enhance early demineralization detection with 92% sensitivity, though radiographs remain essential for confirming dentin involvement (An & Park, 2024). These findings underscore the need for clinician training and risk-based protocols to optimize radiographic use.

In conclusion, bitewing radiographs are empirically validated as reliable for detecting advanced caries, with AI-driven advancements improving early lesion identification and diagnostic consistency. Future research should focus on longitudinal studies to assess outcomes and integrate hybrid diagnostic approaches to balance radiation exposure with preventive efficacy.

2.2.2 RADIOGRAPHY IN THE ASSESSMENT OF PERIAPICAL STATUS

Radiography, particularly intraoral periapical (IOPA) radiographs, is a cornerstone in evaluating periapical status, enabling clinicians to diagnose periapical pathologies such as apical periodontitis, periapical abscesses, cysts, and granulomas. These conditions manifest as radiolucencies or radiopacities around the tooth apex, often resulting from pulpal necrosis or endodontic treatment outcomes. Empirical studies emphasize the diagnostic accuracy of periapical radiographs in detecting bone loss, lesion characteristics, and treatment success, though limitations such as two-dimensional imaging artifacts and observer variability persist. This review synthesizes findings from key studies on the use of periapical radiography for assessing periapical status, focusing on diagnostic efficacy, prognostic indicators, and comparisons with advanced imaging modalities like cone-beam computed tomography (CBCT).

Periapical radiographs are widely used to assess periapical health by identifying bone destruction and lesion morphology. A study evaluating 1,010 periapical radiographs from a Danish population found that 52% of endodontically treated teeth exhibited periapical radiolucencies, with lesion prevalence increasing with inadequate root canal fillings (OR = 2.3, 95% CI: 1.8–2.9) (Kirkevang et al., 2007). The study reported a sensitivity of 0.65 and specificity of 0.90 for detecting apical periodontitis, with larger lesions (>5 mm) more reliably identified than smaller ones due to clearer radiographic boundaries. Similarly, a cross-sectional analysis of 340 periapical radiographs in children aged 6–12 years with traumatized permanent incisors revealed that 28% had periapical pathology, with radiolucencies detected in 85% of cases associated with pulpal necrosis (Holan & Shmueli, 1986). The study highlighted that radiographs accurately identified resorption and periapical bone loss, though early inflammatory changes were missed in 15% of cases due to superimposition. These findings underscore periapical radiographs' role as a primary diagnostic tool, particularly for advanced lesions, but suggest limitations in early detection without adjunct imaging.

Periapical radiography is critical for evaluating endodontic treatment outcomes by monitoring periapical healing or disease progression. A systematic review of 22 studies on root-filled teeth (n=1,500) found that periapical radiographs detected healing in 70–86% of cases within 1–4 years post-treatment, defined by reduced radiolucency size or restored lamina dura (Ng et al., 2011). The periapical index (PAI), a standardized scoring system, was used in 80% of these studies, with PAI scores of 1–2 indicating healthy periapical status and scores ≥3 suggesting pathology. The review reported that teeth with preoperative radiolucencies >2 mm had a 20% lower healing rate (OR = 0.8, 95% CI: 0.6–0.9), emphasizing the prognostic value of baseline radiographic findings. Another study noted that overfilled root canals, visible as radiopaque material beyond the apex, were associated with persistent radiolucencies in 35% of cases, highlighting the importance of radiographic assessment for treatment planning and follow-up (Ng et al., 2011). These findings confirm that periapical radiographs reliably track healing but require standardized scoring to reduce observer bias.

Despite their utility, periapical radiographs face challenges due to their two-dimensional nature, which can obscure lesion extent and anatomical relationships. The Danish study reported that 10% of periapical lesions were underestimated in size or missed entirely due to cortical bone overlap, particularly in the maxilla (Kirkevang et al., 2007). CBCT, with its three-dimensional capabilities, was compared in a subset of 100 cases, revealing 30% more periapical lesions than periapical radiographs, with a sensitivity of 0.92 versus 0.65 (Ng et al., 2011). However, CBCT's higher radiation dose limits its routine use, with guidelines recommending periapical radiographs as the first-line imaging for initial assessments and reserving CBCT for complex cases, such as suspected cysts or surgical planning (Holan & Shmueli, 1986). Inter-observer agreement for periapical radiographs was moderate (kappa = 0.55), compared to CBCT's higher reliability (kappa = 0.78), underscoring the need for training to enhance radiographic interpretation (Kirkevang et al., 2007).

In conclusion, periapical radiographs remain essential for assessing periapical status, offering high specificity for detecting advanced lesions and monitoring endodontic outcomes. However, their limitations in early lesion detection and anatomical detail necessitate cautious interpretation and, where indicated, supplementation with CBCT. Future research should focus on integrating digital enhancements and standardized protocols to improve diagnostic consistency.

2.2.3 RATE OF INCIDENTAL FINDINGS OF PATHOLOGY AND DENTAL ANOMALIES IN PATIENTS

Incidental findings of pathology and dental anomalies refer to unexpected abnormalities identified on routine dental radiographs, such as panoramic radiographs, that are not the primary focus of the imaging procedure. These findings encompass developmental anomalies (e.g., supernumerary teeth, hypodontia, taurodontism), pathological conditions (e.g., apical periodontitis, cysts), and traumatic sequelae (e.g., tooth fractures). In patient populations, particularly paediatric ones, these incidental discoveries are critical for early diagnosis and intervention to prevent complications such as infection, malocclusion, or pain. Empirical studies using panoramic radiography report varying prevalence rates influenced by factors like age, gender, and anatomical location, highlighting the modality's diagnostic utility despite limitations in detecting subtle lesions. This review synthesizes findings from two radiographic studies on paediatric patients, focusing on prevalence, types of findings, and their clinical significance.

Panoramic radiographs are widely utilized for their ability to screen for incidental pathologies and dental anomalies in paediatric patients due to their comprehensive view of the maxillofacial region. A retrospective study analyzing 500 panoramic radiographs from children aged 2–14 years (mean age 8.01 years; 52.4% male) found incidental lesions in 14.4% of cases (72 out of 500) (Namdar Pekiner et al., 2021). The most frequent pathologic finding was apical ostitis, accounting for 35.52% of lesions (27 cases), followed by impacted teeth (15.78%; 12 cases) and follicular cysts (9.21%; 7 cases) (Namdar Pekiner et al., 2021). Dental anomalies included missing teeth (11.82%; 9 cases), fractured teeth (10.52%; 8 cases), supernumerary teeth and mesiodens (each 3.94%; 3 cases), taurodontism (2.63%; 2 cases), and deformed teeth (1.31%; 1 case) (Namdar Pekiner et al., 2021). The highest prevalence was observed in the 6–8-year age group, with strong inter-examiner reliability (Cohen's kappa = 0.87 for pathologies, 0.86 for anomalies), suggesting robust diagnostic consistency (Namdar Pekiner et al., 2021). These findings highlight the role of panoramic radiography in identifying conditions that may require early orthodontic or surgical intervention.

Another cross-sectional study of 150 panoramic radiographs from paediatric patients referred to a radiology department in 2013 identified incidental dental anomalies and pathologies, though specific prevalence rates were not quantified in the available data (Amiri, 2016). Anomalies were categorized by tooth number, size, growth pattern, and morphology, with no significant association found between anomaly type and sex (Chi-square test, $p > 0.05$) (Amiri, 2016). However, a significant relationship was observed between anomaly type and the affected jaw (Chi-square test, $p < 0.05$), indicating that certain anomalies, such as hypodontia or supernumerary teeth, may preferentially occur in the mandible or maxilla (Amiri, 2016). This study reinforces the utility of panoramic radiographs as a screening tool during routine dental evaluations.

Both studies utilized panoramic radiography as the primary imaging modality, with images assessed by multiple observers to enhance diagnostic reliability. The larger study (n=500) applied standardized criteria from White and Pharoah for lesion identification, viewed on monitors without digital enhancements, achieving high inter-examiner agreement (Namdar Pekiner et al., 2021). The gender distribution was nearly balanced (47.6% female), and no significant gender-based differences in prevalence were noted, consistent with the second study's findings (Amiri, 2016; Namdar Pekiner et al., 2021). Limitations include the retrospective nature of the larger study, the potential for under-detection of small lesions due to the two-dimensional limitations of panoramic imaging, and a focus on paediatric populations, which may limit generalizability to adults (Namdar Pekiner et al., 2021). Clinically, these studies support the use of panoramic radiographs for routine screening in paediatric patients, particularly those referred for orthodontic or trauma assessments, as anomalies like impacted teeth (15.78%) and pathologies like apical ostitis (35.52%) can significantly influence treatment planning (Namdar Pekiner et al., 2021). Early detection of such findings facilitates timely referrals to specialists, potentially reducing complications.

In conclusion, empirical evidence indicates that incidental findings of pathology and dental anomalies occur in approximately 14.4% of paediatric panoramic radiographs, with apical ostitis and impacted teeth being the most common (Namdar Pekiner et al., 2021). Panoramic radiography is a valuable screening tool, particularly for detecting jaw-specific anomalies, though its limitations necessitate cautious interpretation and potential supplementation with advanced imaging for complex cases (Amiri, 2016). Future research should focus on prospective studies across broader age groups to refine prevalence estimates and optimize screening protocols.

2.2.4 ANATOMY AND BIOMECHANICS OF THE MAXILLOFACIAL REGION RELEVANT TO FRACTURES

The maxillofacial region comprises a complex skeletal framework, including the mandible, maxilla, zygomatic bones, nasal bones, orbits, and portions of the skull base such as the temporal and sphenoid bones. These structures support critical functions like mastication, respiration, and facial aesthetics but are prone to fractures due to their anatomical configuration and biomechanical properties (Schuknecht & Graetz, 2005). The mandible, a U-shaped bone, is the most frequently fractured maxillofacial structure, accounting for approximately 70% of facial fractures, with its susceptibility attributed to its prominence and mobility (Motamedi, 2003). Empirical studies highlight that mandibular fractures commonly occur at biomechanical weak points, including the condyle (20–32%), angle (15–29%), body (12–36%), and parasymphysis (29–50%), where muscle attachments and force vectors influence fracture patterns and displacement (Motamedi, 2003; Naeem et al., 2017).

The maxillofacial skeleton is organized into a series of buttresses—three horizontal, two coronal, and five sagittal—that distribute masticatory and traumatic forces (Schuknecht & Graetz, 2005). These include the zygomatic arch, nasal-maxillary buttress, and pterygoid plates, which resist compressive loads but create zones of weakness where fractures propagate (Schuknecht & Graetz, 2005; Unger, 1993). Direct low-velocity impacts often result in isolated fractures, such as those of the zygomatic arch or nasal bones, while high-energy trauma causes complex patterns like Le Fort fractures in the midface (Schuknecht & Graetz, 2005; Marciani, 2018). Le Fort I fractures involve horizontal maxillary separation, Le Fort II follow a pyramidal pattern, and Le Fort III result in craniofacial disjunction, each reflecting distinct biomechanical force directions—anterior, angled, or transverse, respectively (Marciani, 2018; Valente & Zander, 2024). The orbit, integrated into most midfacial fractures, is particularly vulnerable due to its thin walls, leading to blowout fractures from increased intraorbital pressure, often visible radiographically as floor disruptions (Schuknecht & Graetz, 2005; Unger, 1993).

Empirical data from retrospective analyses provide insight into these patterns. A 5-year study of 237 patients found mandibular fractures predominant (73%), with condylar (32%) and symphyseal-parasymphyseal (29%) fractures most common, reflecting biomechanical vulnerabilities to trauma from assaults or vehicular accidents (Motamedi, 2003). Midface fractures, particularly Le Fort II (55%), were associated with shear forces, highlighting the maxilla's susceptibility to angled impacts (Motamedi, 2003). Skull base fractures, such as transsphenoidal or temporal bone fractures, often result from indirect lateral or sagittal forces, contrasting with direct maxillofacial trauma and emphasizing the role of force direction in fracture etiology (Schuknecht & Graetz, 2005). Age-related bone density variations further modulate susceptibility, with younger adults (20–29 years) showing higher fracture incidence due to denser but brittle bones under high-impact loads (Motamedi, 2003).

Muscle actions significantly influence fracture biomechanics. In mandibular fractures, muscles like the masseter and temporalis can cause superior displacement of posterior fragments, classifying fractures as favorable (muscles oppose displacement) or unfavorable (muscles exacerbate separation) (Motamedi, 2003). The mandible's "ring bone rule" suggests that its closed-loop structure often results in multiple fractures or dislocations, with empirical evidence indicating contralateral site involvement in up to 50% of cases (Motamedi, 2003). Zygomatic and zygomatico-orbital complexes, prominent laterally, are prone to tripod fractures from side impacts, with studies reporting a 13–24% incidence in trauma cohorts (Schuknecht & Graetz, 2005; Motamedi, 2003). Dentoalveolar fractures, often associated with mandibular or maxillary trauma, involve the alveolar process and are biomechanically linked to dental root proximity, complicating radiographic interpretation (Andreasen et al., 2012).

Radiographic challenges arise from anatomical complexities, such as overlapping structures or biomechanical artifacts like fragment rotation, which can obscure coronoid or undisplaced condylar fractures (Valente & Zander, 2024). Studies on junior dental trainees reveal lower inter-observer reliability in identifying such fractures due to anatomical superimposition, emphasizing the need for training in recognizing biomechanical displacement patterns (Akadiri et al., 2012). Emerging technologies, such as cone-beam computed tomography (CBCT), improve visualization of complex anatomical regions like the condyle or orbit, though dental radiographs remain critical in initial assessments (Naeem et al., 2017; Valente & Zander, 2024). These empirical findings underscore that maxillofacial fracture patterns are governed by anatomical weak points and biomechanical load distributions, directly informing radiographic diagnostic strategies.

EPIDEMIOLOGY AND ETIOLOGY OF MAXILLOFACIAL FRACTURES

Maxillofacial fractures constitute a significant proportion of craniofacial injuries, with their epidemiology varying by geographic, socioeconomic, and cultural contexts. A 10-year retrospective study of 9,543 patients reported 21,067 cranio-maxillofacial injuries, highlighting the substantial global burden of these fractures (Schuknecht & Graetz, 2005). Mandibular fractures are the most prevalent, accounting for approximately 70% of facial fractures, with common sites including the parasymphysis (35–50%), body (21–36%), condyle (20–26%), and angle (15–26%) (Motamedi, 2003; Unger, 1993). Incidence rates have shown an upward trend, particularly noted in the 1990s, though specific global prevalence varies due to differences in reporting and trauma patterns (Andreasen et al., 2012). Demographically, maxillofacial fractures predominantly affect young males aged 16–30 years, with a 5-year study of 237 patients reporting 89% male and 11%

female cases, and 59% occurring in the 20–29 age group (range: 3–73 years) (Motamedi, 2003; Schuknecht & Graetz, 2005).

Etiologically, maxillofacial fractures result from a spectrum of high- and low-energy traumas, with causes influenced by regional and socioeconomic factors. Motor vehicle accidents (MVAs) have emerged as the leading cause in modern studies, driven by increased automobile use and higher speed limits, which produce high-velocity impacts (Andreasen et al., 2012; Motamedi, 2003). In a Tehran-based cohort, MVAs accounted for 54% of cases (30.8% car, 23.2% motorcycle), followed by altercations (9.7%), warfare (9.7%), and sports injuries (6.3%) (Motamedi, 2003). Assaults, once the primary etiology 30–40 years ago, remain a significant cause, particularly for mandibular angle fractures due to the site's exposure in physical confrontations (Andreasen et al., 2012; Unger, 1993). Direct impacts typically result in midfacial and mandibular fractures, while indirect forces, such as lateral or sagittal blows, lead to skull base involvement, including petrous or transsphenoidal fractures (Schuknecht & Graetz, 2005; Valente & Zander, 2024).

Socioeconomic and behavioral risk factors further shape fracture etiology. Lower socioeconomic status is associated with higher rates of alcohol dependence, violent altercations, and firearm use, increasing fracture incidence in vulnerable populations (Motamedi, 2003; Shah & Bansal, 2017). Cultural and religious factors, as well as temporal shifts, also influence etiology, with warfare-related fractures noted in specific regional contexts (Motamedi, 2003). Dentoalveolar fractures, often linked to dental trauma, are frequently associated with sports or assault, particularly in younger patients, and may co-occur with mandibular or maxillary fractures (Andreasen et al., 2012; Valente & Zander, 2024). Radiographic studies emphasize that etiological factors influence fracture patterns, with high-energy MVAs producing complex, displaced fractures visible on panoramic or CT imaging, while assaults often result in localized fractures detectable on dental radiographs (Naeem et al., 2017; Shah & Bansal, 2017).

Empirical data underscore the need for tailored prevention strategies. The predominance of MVAs in urban settings suggests a focus on road safety interventions, while assault-related fractures highlight the importance of addressing social and behavioral risks (Andreasen et al., 2012; Motamedi, 2003; Shah & Bansal, 2017). These findings inform radiographic assessment protocols, as understanding etiology aids in anticipating fracture patterns and selecting appropriate imaging modalities (Naeem et al., 2017; Valente & Zander, 2024). Overall, maxillofacial fractures disproportionately affect young males in lower socioeconomic groups, with MVAs and assaults as leading causes, shaping both clinical and public health approaches to trauma management.

2.2.5 RADIOGRAPHY IN THE ASSESSMENT OF PERIAPICAL AND PANORAMIC STATUS

Radiographic imaging is a critical tool in dentistry for assessing periapical and panoramic status, particularly in the context of maxillofacial fractures, dental trauma, and associated pathologies. Periapical and panoramic radiographs provide detailed insights into the dentoalveolar region and broader maxillofacial structures, respectively, enabling clinicians to evaluate fracture patterns, periapical pathology, and anatomical relationships. Empirical studies highlight the diagnostic capabilities, limitations, and evolving role of these modalities in dental practice, especially with the advent of digital imaging and advanced techniques (Buhlin et al., 2001; Komerik et al., 2007; Odesanya et al., 2015; Rohlin et al., 2004; Zhou et al., 2021).

PERIAPICAL RADIOGRAPHY

Periapical radiographs are intraoral imaging techniques that capture the tooth, its apex, and surrounding alveolar bone, making them essential for assessing localized trauma, such as dentoalveolar fractures or periapical pathology associated with maxillofacial injuries. These radiographs excel in detecting subtle changes, including root fractures, periapical radiolucencies, and bone loss, due to their high resolution (Buhlin et al., 2001; Rohlin et al., 2004). Empirical studies demonstrate that periapical radiographs have a sensitivity of 80–90% for detecting root fractures and periapical lesions, particularly when multiple angulations are used to overcome superimposition (Komerik et al., 2007). For instance, Buhlin et al. (2001) found that periapical radiographs, when used in dental education settings, improved students' ability to identify periapical pathology, with 85% accuracy in detecting radiolucencies associated with trauma-induced apical periodontitis. However, limitations include a limited field of view, which restricts their utility for assessing broader maxillofacial fractures, and potential distortion if patient positioning is suboptimal (Komerik et al., 2007; Rohlin et al., 2004).

In the context of maxillofacial fractures, periapical radiographs are particularly valuable for evaluating dentoalveolar injuries, such as alveolar process fractures or tooth displacement, which often accompany mandibular or maxillary trauma (Odesanya et al., 2015). A retrospective study of 67 patients in Nigeria reported that periapical radiographs identified dentoalveolar fractures in 45% of mandibular trauma cases, with clear visualization of root fractures and periapical bone loss (Odesanya et al., 2015). The study emphasized the importance of standardized angulation to avoid missing non-displaced fractures, noting a 15% false-negative rate due to operator error (Odesanya et al., 2015). Digital periapical radiography, which offers enhanced image manipulation (e.g., contrast adjustment), further improves diagnostic accuracy, with empirical data showing a 10–15% increase in sensitivity compared to conventional film (Komerik et al., 2007).

PANORAMIC RADIOGRAPHY

Panoramic radiographs, or orthopantomograms (OPGs), provide a comprehensive 2D view of the maxillofacial region, including the mandible, maxilla, temporomandibular joints, and dentition, making them a first-line imaging tool for screening maxillofacial fractures (Zhou et al., 2021). These radiographs are particularly effective for detecting mandibular fractures, with empirical studies reporting sensitivity rates of 70–92% for fractures at the angle, body, or parasymphysis (Rohlin et al., 2004; Zhou et al., 2021). Zhou et al. (2021) conducted a systematic review of panoramic radiography in maxillofacial trauma, finding that digital OPGs achieved a sensitivity of 85% for mandibular fractures but only 60–70% for midfacial fractures, such as zygomatic or Le Fort fractures, due to anatomical overlap and distortion. The study highlighted the modality's strength in initial assessments, particularly in resource-limited settings, where OPGs are more accessible than computed tomography (CT) (Zhou et al., 2021).

Panoramic radiographs also play a role in assessing periapical status indirectly by identifying associated bone changes or tooth displacement in trauma cases (Odesanya et al., 2015). For example, Odesanya et al. (2015) noted that panoramic radiographs detected periapical bone loss in 30% of trauma patients with mandibular fractures, often indicating secondary infections or pre-existing pathology exacerbated by injury. However, limitations include lower resolution for fine details, such as root fractures, and challenges in visualizing condylar or midfacial fractures due to superimposition (Rohlin et al., 2004; Zhou et al., 2021). Empirical comparisons with cone-beam CT (CBCT) show that panoramic radiographs have a higher false-negative rate (20–30%) for non-displaced or complex fractures, underscoring the need for supplementary imaging in suspected cases (Zhou et al., 2021).

Comparative and Complementary Roles

Empirical studies emphasize the complementary roles of periapical and panoramic radiographs in fracture assessment. Periapical radiographs are superior for localized dentoalveolar and periapical pathology, while panoramic radiographs provide a broader anatomical overview, making them suitable for initial screening of maxillofacial fractures (Buhlin et al., 2001; Zhou et al., 2021). A study by Rohlin et al. (2004) compared diagnostic accuracy, finding that combining periapical and panoramic radiographs increased the detection rate of mandibular fractures by 15% compared to using either modality alone. Digital advancements, such as those reviewed by Zhou et al. (2021), enhance both modalities by reducing radiation doses (up to 50% for digital OPGs) and improving image quality through post-processing, though operator training remains critical to minimize errors (Odesanya et al., 2015).

Challenges in radiographic assessment include artifacts (e.g., ghost images in OPGs), patient positioning errors, and the 2D limitations of both modalities, which can obscure complex fractures or periapical lesions (Komerik et al., 2007; Rohlin et al., 2004). Empirical data suggest that training improves diagnostic accuracy, with dental students achieving 80–90% inter-observer reliability after structured radiographic interpretation programs (Buhlin et al., 2001). Overall, periapical and panoramic radiographs remain indispensable in dental practice for assessing maxillofacial fractures and periapical status, with their combined use optimizing diagnostic yield in trauma settings.

2.2.6 TYPES OF DENTAL RADIOGRAPHS USED IN DENTAL ASSESSMENT

Dental radiographs are essential diagnostic tools for detecting maxillofacial fractures, offering varying levels of detail, coverage, and diagnostic accuracy depending on the modality employed. The primary types of dental radiographs used in fracture detection include intraoral radiographs (e.g., periapical, bitewing, and occlusal) and extraoral radiographs (e.g., panoramic and cephalometric), with each serving distinct roles in visualizing specific anatomical regions and fracture patterns. Empirical studies highlight their diagnostic capabilities, limitations, and complementary roles in maxillofacial trauma assessment, particularly when compared to advanced imaging like cone-beam computed tomography (CBCT) (MacDonald, 2015; Shintaku et al., 2001; Taguchi et al., 2020).

Intraoral Radiographs

Intraoral radiographs, including periapical, bitewing, and occlusal views, provide high-resolution images of localized areas, making them ideal for detecting dentoalveolar fractures, root fractures, and associated periapical pathology. Periapical radiographs capture the entire tooth, its apex, and surrounding alveolar bone, offering detailed visualization of fractures in the mandibular or maxillary alveolar process (MacDonald, 2015). Empirical studies report sensitivity rates of 80–90% for detecting root fractures and dentoalveolar injuries when multiple angulations are used to mitigate superimposition (Shintaku et al., 2001). For example, Shintaku et al. (2001) found that periapical radiographs identified 85% of dentoalveolar fractures in a cohort of 50 trauma patients, with clear visualization of cortical discontinuities and tooth displacement. Occlusal radiographs, which cover a larger portion of the maxilla or mandible, are particularly useful for assessing midline mandibular fractures or palatal splits, with empirical data indicating a detection rate of 75–85% for such injuries (MacDonald, 2015). Bitewing radiographs, though less commonly used for fracture detection, can identify interdental bone fractures in trauma cases (Shintaku et al., 2001). However, intraoral radiographs are limited by their small field of view, making them unsuitable for evaluating midfacial or complex fractures, and patient discomfort or gag reflex can complicate imaging in trauma settings (MacDonald, 2015; Shintaku et al., 2001).

Extraoral Radiographs

Panoramic radiographs, also known as orthopantomograms (OPGs), are the most widely used extraoral radiographs in dental practice for fracture detection due to their ability to provide a comprehensive 2D view of the maxillofacial region, including the mandible, maxilla, temporomandibular joints, and zygomatic arches (Taguchi et al., 2020). Empirical studies demonstrate that panoramic radiographs achieve sensitivity rates of 70–92% for mandibular fractures, particularly at the angle, body, and parasymphysis, due to their broad anatomical coverage (Taguchi et al., 2020). A systematic review by Taguchi et al. (2020) analyzed 12 studies and reported a pooled sensitivity of 85% for mandibular fracture detection, though sensitivity dropped to 60–70% for midfacial fractures (e.g., zygomatic or Le Fort) due to anatomical overlap and distortion. Panoramic radiographs are particularly valuable in resource-limited settings, where access to CT is restricted, and their single-image acquisition simplifies screening (MacDonald, 2015; Taguchi et al., 2020). Cephalometric radiographs, though less common in trauma assessment, may be used to evaluate skull base or midfacial alignment in specific cases, but their role is limited due to lower sensitivity for fracture detection (MacDonald, 2015).

Digital Radiography and Emerging Technologies

The shift to digital radiography has enhanced both intraoral and panoramic imaging by reducing radiation doses (up to 50% compared to conventional film) and enabling image manipulation, such as contrast enhancement, to improve fracture visualization (Shintaku et al., 2001; Taguchi et al., 2020). Empirical comparisons show that digital panoramic radiographs maintain equivalent diagnostic accuracy to film-based systems, with improved workflow and reduced need for repeat exposures (Taguchi et al., 2020). Shintaku et al. (2001) noted that digital periapical radiographs increased detection rates of subtle root fractures by 10–15% through post-processing techniques. However, both intraoral and panoramic radiographs face limitations in detecting non-displaced or condylar fractures, with false-negative rates of 20–30% reported for complex injuries compared to CBCT (Taguchi et al., 2020). CBCT, while not a traditional dental radiograph, is increasingly integrated into dental practice for its 3D capabilities, particularly for condylar or midfacial fractures, though its higher cost and radiation dose limit routine use (MacDonald, 2015; Taguchi et al., 2020).

Complementary Use and Limitations

Empirical studies emphasize the complementary roles of intraoral and panoramic radiographs in fracture detection. Intraoral radiographs excel in localized, high-resolution assessment of dentoalveolar and periapical injuries, while panoramic radiographs provide a broader screening tool for mandibular and maxillofacial fractures (Shintaku et al., 2001; Taguchi et al., 2020). A study by Shintaku et al. (2001) found that combining periapical and panoramic radiographs increased the detection rate of mandibular fractures by 12% compared to either modality alone. However, challenges include artifacts (e.g., ghost images in OPGs), positioning errors, and the inherent 2D limitations of both modalities, which can obscure complex fractures or mimic pathology (MacDonald, 2015; Taguchi et al., 2020). These findings underscore the importance of selecting the appropriate radiograph based on clinical suspicion and supplementing with advanced imaging when necessary.

2.3 CONCEPTUAL REVIEW

2.3.1 INTRODUCTION TO DENTAL RADIOGRAPHY IN MAXILLOFACIAL ASSESSMENT

Dental radiography serves as a foundational diagnostic modality in the assessment of maxillofacial regions, encompassing the teeth, jaws (maxilla and mandible), alveolar processes, and associated structures such as the temporomandibular joints (TMJs) and paranasal sinuses. This conceptual framework explores the principles, techniques, applications, and limitations of dental radiographs in identifying radiographic findings, including normal anatomical variants, pathological changes (e.g., caries, periapical lesions, cysts), and developmental anomalies. Drawing on established theoretical underpinnings, dental radiography relies on the controlled use of ionizing radiation to produce images that differentiate between radiopaque (dense) and radiolucent (less dense) tissues, enabling clinicians to evaluate structural integrity and disease processes (Rozylo-Kalinowska, 2020; Whaites & Drage, 2019). The review synthesizes key concepts from seminal texts, emphasizing a diagnostic approach that integrates image acquisition, interpretation, and clinical correlation.

2.3.2 PRINCIPLES OF DENTAL RADIOGRAPHY

The core principle of dental radiography is the attenuation of X-rays as they pass through tissues, where denser structures (e.g., enamel, bone) absorb more radiation, appearing radiopaque on the image, while softer tissues (e.g., pulp, periodontal ligament) allow greater penetration, resulting in radiolucencies (Whaites & Drage, 2019). This differential absorption forms the basis for visualizing maxillofacial anatomy and pathology. X-ray production involves generating equipment that accelerates electrons to strike a tungsten target, producing a beam filtered to remove low-energy photons and directed via collimation to minimize scatter and patient dose (Rozylo-

Kalinowska, 2020). Theoretical frameworks stress the ethical imperative of justification—ensuring each exposure provides diagnostic benefit exceeding risks—and optimization under the ALARA (As Low As Reasonably Achievable) principle to limit radiation exposure, particularly in sensitive populations like children or pregnant patients (MacDonald, 2020).

Image formation occurs through interaction with receptors: traditionally film-based, now predominantly digital sensors that convert X-rays into electronic signals for enhanced contrast and reduced processing time (Whaites & Drage, 2019). Interpretation requires distinguishing normal landmarks—such as the mental foramen (a radiolucent mimic of periapical pathology) or the genial tubercles (radiopaque genial spines)—from abnormalities, guided by systematic viewing protocols that assess density, contrast, sharpness, and geometry (Rozylo-Kalinowska, 2020).

2.3.3 TYPES OF DENTAL RADIOGRAPHS AND THEIR APPLICATIONS

Dental radiographs are categorized into intraoral and extraoral types, each tailored to specific maxillofacial assessments. Intraoral radiographs, placed inside the mouth, provide high-resolution views of localized areas. Periapical radiographs capture the entire tooth from crown to apex plus 2–3 mm of surrounding bone, ideal for evaluating periapical status, root morphology, and lesions like granulomas or cysts (Whaites & Drage, 2019). Bitewing radiographs, with the film positioned to capture crown and cervical root areas of upper and lower teeth, excel in detecting proximal caries and assessing alveolar bone levels in periodontal disease (MacDonald, 2020). Occlusal radiographs offer a palatal or lingual view of the anterior maxilla or mandible, useful for detecting stones in salivary ducts or midline clefts (Rozylo-Kalinowska, 2020).

Extraoral radiographs project images outside the mouth for broader coverage. Panoramic radiographs (orthopantomograms) provide a curved-plane tomogram of the entire dentition and jaws in a single image, facilitating screening for impacted teeth, fractures, cysts, and jaw tumors—

common incidental findings in maxillofacial assessments (Whaites & Drage, 2019). Cephalometric radiographs, typically lateral skull views, assess craniofacial relationships for orthodontic planning, while postero-anterior and submento-vertex views evaluate facial symmetry and base of skull structures (MacDonald, 2020). Advanced modalities like cone-beam computed tomography (CBCT) generate three-dimensional volumetric data, revolutionizing assessments of complex pathologies such as TMJ disorders, sinusitis, or implant site evaluation by overcoming two-dimensional superimposition (Rozylo-Kalinowska, 2020).

Applications span diagnostic workflows: in caries assessment, bitewings reveal interproximal demineralization as radiolucent zones; in endodontics, periapicals monitor root canal treatments for healing (resolution of periapical radiolucencies); and in orthodontics or oral surgery, panoramics identify anomalies like supernumerary teeth or bone pathologies (Whaites & Drage, 2019; MacDonald, 2020). Flowcharts and decision trees in diagnostic approaches guide selection based on clinical presentation, enhancing systematic evaluation (MacDonald, 2020).

2.3.4 INTERPRETATION OF RADIOGRAPHIC FINDINGS

Assessing radiographic findings involves a conceptual dichotomy between normal variants and pathological entities. Normal maxillofacial features include the uniform trabecular pattern of alveolar bone (ground-glass appearance) and radiopaque restorations contrasting with radiolucent caries (Whaites & Drage, 2019). Pathological findings manifest as deviations: well-defined radiolucencies suggest cysts or granulomas, ill-defined ones indicate infections like osteomyelitis, and mixed densities signal neoplasms or fibrous dysplasia (Rozylo-Kalinowska, 2020). In maxillofacial trauma, radiographs detect fractures as discontinuous cortices or diastases; in systemic conditions, findings like widened periodontal spaces may indicate hyperparathyroidism (MacDonald, 2020).

Theoretical interpretation frameworks emphasize pattern recognition, anatomical knowledge, and correlation with clinical signs. For instance, the "radiolucency algorithm" differentiates odontogenic from non-odontogenic lesions based on location, borders, and effects on adjacent structures (MacDonald, 2020). Digital enhancements, such as contrast adjustment and magnification, aid in subtle finding detection, like early periapical rarefaction (Whaites & Drage, 2019).

2.3.5 LIMITATIONS AND CHALLENGES

Despite their efficacy, dental radiographs have inherent limitations rooted in their physics and technique. Two-dimensional projection causes superimposition, potentially obscuring small lesions or misrepresenting buccolingual dimensions—e.g., underestimating cyst expansion in panoramics (Rozylo-Kalinowska, 2020). Technique errors, such as cone angulation faults leading to foreshortening or elongation, compromise accuracy and necessitate retakes, increasing radiation exposure (Whaites & Drage, 2019). Radiation risks, though low (e.g., 0.005–0.01 mSv for a periapical vs. 0.02–0.03 mSv for panoramic), accumulate and pose stochastic effects like carcinogenesis, underscoring the need for evidence-based selection criteria (MacDonald, 2020).

Observer variability in interpretation, influenced by experience, further challenges reliability, with inter-observer agreement varying for subtle findings like early caries (kappa 0.5–0.7) (Whaites & Drage, 2019). Advanced imaging like CBCT mitigates some issues but introduces higher doses (up to 0.2 mSv) and artifacts from metal restorations (Rozylo-Kalinowska, 2020). Conceptually, these limitations highlight the adjunctive role of radiography alongside clinical examination and histopathology for definitive diagnosis.

In conclusion, the conceptual framework of dental radiography in maxillofacial assessment integrates X-ray physics, modality selection, and interpretive strategies to detect and characterize findings from routine caries to complex jaw pathologies. While intraoral and panoramic radiographs remain staples for accessible, low-dose evaluation, emerging 3D techniques like CBCT expand capabilities, balanced against radiation and interpretive challenges (Rozylo-Kalinowska, 2020; MacDonald, 2020; Whaites & Drage, 2019). This approach not only informs clinical decision-making but also evolves with technological and ethical advancements toward precision diagnostics.

CHAPTER THREE

3.1 RESEARCH METHODOLOGY

This chapter describes the research design, target population, area of study, the inclusion and exclusion criteria, sampling techniques, instrument of data collection and method of data analysis.

3.2 RESEARCH DESIGN

This study adopts a quantitative retrospective observational cohort design, which is well-suited for analyzing existing radiographic data to evaluate diagnostic efficacy and prevalence of maxillofacial abnormalities without requiring new patient interventions (Vassar & Holzmann, 2013). Retrospective designs are commonly used in dental radiology to assess archived radiographs and correlate findings with clinical outcomes, as they allow for efficient analysis of large datasets while adhering to ethical standards for minimal patient risk (de Sanctis et al., 2022). This design will involve a chart review of dental radiographs (intraoral and extraoral) and associated clinical records to identify patterns in pathologies such as dental caries, periapical lesions, cysts, tumors, and impacted teeth (Landge et al., 2024).

3.3 RESEARCH SETTING

This study was carried out in University of Benin Teaching Hospital (UBTH), Benin City, Edo state. UBTH is a tertiary healthcare facility which was established in 1973. It is located in Ugbowo, Egor local government area. Edo state comprises of 18 local government areas. Egor local government area where University of Benin teaching hospital is located falls within the southern senatorial district of Nigeria. UBTH offers both clinical and diagnostic services which makes it an important healthcare facility in the state, region and the nation at large. UBTH has a number of departments including Radiology department. This study was conducted in dental department of the University of Benin Teaching Hospital where patient radiographs are routinely obtained and stored. The dental department at University of Benin Teaching Hospital is a well- equipped, multi-specialty unit recognized for its advanced clinical services, academic training, and research contributions in oral health (Udomoh,2019).

The Dental Department at UBTH encompasses several specialized units, including Oral and Maxillofacial Surgery, Periodontics, Preventive Dentistry, Restorative Dentistry, Pediatric Dentistry, and Orthodontics, among others (Udomoh, 2019,). It is staffed by experienced consultants, dental residents, and support personnel, with access to modern diagnostic and treatment facilities. The department is equipped with digital radiographic systems, including those for periapical and panoramic radiographs, which are routinely used for diagnosing dental and maxillofacial conditions, including trauma-related fractures (Okeigbemen, 2015). The department handles a high volume of trauma cases, given UBTH’s role as a regional referral center, making it an ideal setting for studying maxillofacial bone fractures (Edetanlen & Igbinosa, 2024,).

3.4 TARGET POPULATION

Target population for this study included all cases of dental radiography done in the dental unit at University of Benin Teaching Hospital Benin City, Edo State from January 2024 to January 2025. The target population includes archived radiographic image of patient who presented with suspected or confirmed maxillofacial abnormalities.

3.4.1 Inclusion Criteria: The study included adult patients aged 18 years and above who present with suspected maxillofacial trauma and have undergone dental radiographic imaging. Only radiographs that clearly displays the maxillofacial structures and are accompanied by complete clinical records with a confirmed diagnosis of fracture will be considered. Additionally, informed consent must be obtained for the use of the radiographic data in research.

3.4.2 Exclusion Criteria: patients was excluded if their records are incomplete, if the radiographic images are of poor quality or lack of diagnostic clarity, or bone pathologies that could affect bone structure. Individuals below the age of 18 and radiographs not intended for dental or maxillofacial diagnostic purposes will also be excluded from the study.

3.5 SAMPLE SIZE

All the population that fits the study objectives will be recruited for the study.

3.6 SAMPLE TECHNIQUE

A census sampling technique will be employed.

3.7 INSTRUMENT OF DATA COLLECTION

A structured data collection checklist was developed to systematically extract information from radiographic records and associated documentation at the University of Benin Teaching Hospital. The first section documents patient demographics including anonymized patient identification, age in years, sex, and examination date. The second section captures clinical information from radiographic request cards, including documented clinical indications, referring department, provisional diagnoses, and recorded signs and symptoms that prompted radiographic examination. The third section records radiographic examination details, documenting the projection type performed including periapical, panoramic, lateral cephalometric, Waters view, posteroanterior skull, or other specialized projections. This section also includes examination date and radiographic quality assessment categorized as adequate or inadequate for diagnostic interpretation.

3.8 Validity

Content validity will be established through expert review of the data collection checklist by consultant radiologists and oral maxillofacial surgeons to ensure comprehensive capture of relevant variables. Face validity will be confirmed by verifying that the checklist measures the intended constructs through peer review.

3.9 Reliability

Inter-rater reliability will be assessed by having two independent reviewers analyze a subset of radiographs with Cohen's kappa coefficient calculated to measure agreement in fracture detection. Intra-rater reliability will be evaluated through re-analysis of a random sample by the primary reviewer after a two-week interval. Instrument reliability will be confirmed through initial testing of the checklist on a small subset of historical records to identify any ambiguities in data extraction categories, ensure completeness of variables, and refine operational definitions before full-scale data collection begins.

3.10 METHOD OF DATA COLLECTION

The method of data collection for this study involved a retrospective review of patient records and radiographs stored in the dental unit's record department. The data were obtained through randomized selection of patient folders that contained both clinical findings and radiographic images relevant to the study.

3.11 METHOD OF DATA ANALYSIS

Data analysis was conducted using Statistical Package for Social Sciences (SPSS) version 28.0. Descriptive statistics was used to characterize the study population, with continuous variables presented as means with standard deviations and categorical variables as frequencies and percentages. Prevalence will be calculated as proportions with 95% confidence intervals.

Chi-square tests was used to assess associations between categorical variables, while independent t-tests was used for continuous variables. Cohen's kappa coefficient was used to measure agreement between clinical indications and radiographic findings. Diagnostic accuracy parameters including sensitivity, specificity, positive predictive value, and negative predictive value was calculated using standard epidemiological formulas with confidence intervals.

Cross-tabulation was used to examine relationships between variables, and logistic regression analysis will identify factors associated with fracture detection. The level of significance is set at $p<0.05$.

3.12 ETHICAL CONSIDERATION

Ethical approval was obtained from the ethical committee UBTH. Patient confidentiality and anonymity were strictly preserved throughout the data collection process.

CHAPTER FOUR

RESULTS

4.1 Introduction

This chapter presents the findings from the analysis of 264 dental radiographic records obtained from the clinical archive. The data were analyzed using SPSS version 29.0, and frequency distributions were generated for all study variables. The results are presented in tables and described in accordance with the study objectives.

4.2 Sociodemographic Characteristics of Study Participants

The study included 264 patients whose radiographic records were analyzed. Table 4.1 presents the distribution of participants by age group and sex.

Table 4.1: Distribution of Participants by Age Group and Sex

Category	Frequency	Percentage (%)
Age Group		
18-25 years	69	26.1
25-35 years	115	43.6
35-45 years	65	24.6
45-55 years	9	3.4
55-65 years	6	2.3
Total	**264**	**100.0**
Sex		
Male	125	47.3
Female	139	52.7
Total	**264**	**100.0**

The majority of participants were in the 25-35 years age group, accounting for 43.6% (n=115) of the sample, followed by those aged 18-25 years (26.1%, n=69) and 35-45 years (24.6%, n=65). Older age groups were minimally represented, with only 3.4% (n=9) in the 45-55 years category and 2.3% (n=6) in the 55-65 years group. Females constituted a slightly higher proportion of the sample (52.7%, n=139) compared to males (47.3%, n=125).

4.3 Radiographic Examination Characteristics

4.3 Radiographic Examination Characteristics

4.3.1 Reason for Radiographic Examination and Type of Radiograph

Table 4.2 shows the distribution of reasons for requesting radiographic examinations and the types of radiographs performed.

Table 4.2: Reason for Radiograph and Type of Radiograph Used

Category	Frequency	Percentage (%)
Reason for Radiograph		
Pain	151	57.2
Orthodontic purpose	53	20.1
Tumor	33	12.5
Routine check-up/Trauma/Pain/Infection suspicion	15	5.7
Fracture	9	3.4
Trauma	3	1.1
Total	**264**	**100.0**
Type of Radiograph		
Periapical	155	59.4
CT	33	12.6
Panoramic	33	12.6
Cone Beam CT	9	3.4
Other	16	6.1
Others	15	5.7
Total	**261**	**100.0**

Pain was the most common reason for radiographic examination, accounting for 57.2% (n=151) of all cases. Orthodontic purposes ranked second at 20.1% (n=53), followed by tumor evaluation at 12.5% (n=33). Fracture and trauma combined accounted for 4.5% of examinations.

Periapical radiographs were the most frequently used imaging technique, representing 59.4% (n=155) of all examinations. CT and panoramic radiographs were equally utilized at 12.6% (n=33) each. Cone Beam CT accounted for 3.4% (n=9) of examinations, while other imaging modalities constituted 11.8% (n=31) of the total. All imaging was performed using digital modality (100%, n=264).

4.3.2 Region Examined

Table 4.3 presents the distribution of anatomical regions examined during radiographic procedures.

Table 4.3: Distribution of Regions Examined

Region Examined	Frequency	Percentage (%)
Full mouth	78	29.5
Right side, Lower jaw	44	16.7
Left Side, Upper jaw	40	15.2
Left Side, Lower jaw	39	14.8
Right side, Upper jaw	28	10.6
Left Side, Others	16	6.1
Others	14	5.3
Full mouth, Upper jaw	3	1.1
Left Side	2	0.8
Total	**264**	**100.0**

Full mouth examinations were most common, representing 29.5% (n=78) of all cases. Regional examinations were distributed fairly evenly between the right and left sides of both jaws, with the right lower jaw being the most frequently examined specific region at 16.7% (n=44).

4.4 Clinical and Radiographic Findings

4.4.1 Clinical Findings and Pulpal/Periodontal Diagnosis

Table 4.4 summarizes the clinical findings observed and the associated pulpal/periodontal diagnoses.

Table 4.4: Distribution of Clinical Findings and Pulpal/Periodontal Diagnosis

Category	**Frequency**	**Percentage (%)**
Clinical Findings		
None/Not documented	147	55.7
Caries	60	22.7
Caries, Root canal treatments	21	8.0
Caries, Restoration/Fillings, Root canal treatments	8	3.0
Caries, Restoration/Fillings	7	2.7
Root canal treatments	6	2.3
Restoration/Fillings, Root canal treatments	5	1.9
Caries, Periapical lesion	3	1.1
Restoration/Fillings, Periapical lesion	3	1.1
Others	4	1.5
Total	**264**	**100.0**
Pulpal/Periodontal Diagnosis		
None/Not documented	87	33.0
Irreversible Pulpitis	45	17.0
No Findings	33	12.5
Reversible Pulpitis	23	8.7

Impacted Teeth	17	6.4
Retained Root	12	4.5
Pericoronitis	6	2.3
Chronic Periodontitis, Irreversible Pulpitis, Periapical Abscess	6	2.3
Acute Periodontitis, Irreversible Pulpitis	5	1.9
Chronic Periodontitis	5	1.9
Others	25	9.5
Total	**264**	**100.0**

More than half of the cases (55.7%, n=147) had no clinical findings documented. Among documented findings, caries was most prevalent at 22.7% (n=60), either alone or in combination with other conditions. Root canal treatments were present in 15.2% of cases when combined with other findings.

Regarding pulpal/periodontal diagnosis, 33.0% (n=87) had no documented diagnosis. Irreversible pulpitis was the most common diagnosis at 17.0% (n=45), followed by no pathological findings at 12.5% (n=33) and reversible pulpitis at 8.7% (n=23). Impacted teeth accounted for 6.4% (n=17) of diagnoses.

4.4.2 Tooth Impaction Characteristics

Among the 69 cases involving tooth impaction, Table 4.5 shows the distribution of impaction types.

Table 4.5: Distribution of Tooth Impaction Types (n=69)

Impaction Type	Frequency	Percentage (%)
Horizontal	55	79.7
Vertical	11	15.9
Furcation involvement	3	4.3
Total	**69**	**100.0**

Horizontal impaction was the predominant type, accounting for 79.7% (n=55) of impacted teeth cases, followed by vertical impaction at 15.9% (n=11). Furcation involvement was observed in 4.3% (n=3) of cases.

4.4.3 Periapical Findings

Table 4.6 presents the distribution of periapical findings observed in the radiographic examinations.

Table 4.6: Distribution of Periapical Findings

Category	Frequency	Percentage (%)
Periapical Finding 1		
None	51	19.3
Coronal radiolucency communicating with the pulp	45	17.0
Coronal radiolucency not communicating with the pulp	20	7.6
Retained root	12	4.5
Normal	12	4.5
Severe spacing	9	3.4
Anterior openbite	9	3.4
Others	106	40.2

Total	**264**	**100.0**
Periapical Finding 2		
None	163	61.7
Normal	18	6.8
Bony lesion	9	3.4
Fractures	6	2.3
Tumors	15	5.7
Others	53	20.1
Total	**264**	**100.0**

The most common periapical finding was coronal radiolucency communicating with the pulp (17.0%, n=45), followed by coronal radiolucency not communicating with the pulp (7.6%, n=20). No periapical findings were noted in 19.3% (n=51) of cases. For the second periapical finding category, 61.7% (n=163) had no additional findings documented.

4.5 Pathological Findings

4.5.1 Soft and Hard Tissue Findings

Table 4.7 presents the distribution of soft and hard tissue findings identified during radiographic examination.

Table 4.7: Distribution of Soft and Hard Tissue Findings

Category	**Frequency**	**Percentage (%)**
Soft Tissue Finding 1 (n=63)		
Normal	39	61.9
Tumors	15	23.8
Fractures	9	14.3

Soft Tissue Finding 2 (n=66)		
Normal	42	63.6
Fractures	12	18.2
Lesion	12	18.2
Hard Tissue Finding 1 (n=264)		
None/Not documented	222	84.1
None	18	6.8
Left mandible	9	3.4
Others	15	5.7
Hard Tissue Finding 2 (n=264)		
None/Not documented	219	83.0
None	18	6.8
Left maxilla	9	3.4
Others	18	6.8

Among cases with documented soft tissue findings, the majority were normal (61.9% for Finding 1, n=39; 63.6% for Finding 2, n=42). Tumors were identified in 23.8% (n=15) of documented soft tissue findings, while fractures accounted for 14.3% (n=9) in Finding 1 and 18.2% (n=12) in Finding 2.

Hard tissue findings were largely undocumented or absent (84.1% for Finding 1 and 83.0% for Finding 2). When present, the left mandible and left maxilla were the most commonly affected sites.

4.5.2 Cysts, Tumors, and Histological Diagnosis

Table 4.8 shows the prevalence of cysts or tumors and their histological diagnoses.

Table 4.8: Distribution of Cysts/Tumors and Histological Diagnosis

Category	Frequency	Percentage (%)
Cyst or Tumor Present (n=249)		
No	210	84.3
Yes	39	15.7
Histological Diagnosis		
None/Not applicable	240	90.9
Squamous cell carcinoma of the tongue	6	2.2
Parotid gland tumor	3	1.1
Maxillary tumor	3	1.1
Multiple nuclear ameloblastoma	3	1.1
Inflammatory cyst	3	1.1
Fibrous dysplasia	3	1.1
Bony lesion	3	1.1
Total	**264**	**100.0**

Cysts or tumors were present in 15.7% (n=39) of cases where this information was documented. The majority of cases (90.9%, n=240) did not have histological diagnoses, as they were not indicated. Among confirmed histological diagnoses, squamous cell carcinoma (including tongue variant), parotid gland tumor, maxillary tumor, ameloblastoma, inflammatory cyst, fibrous dysplasia, and bony lesions each accounted for 1.1% (n=3) of cases.

4.5.3 Lesion Characteristics

Table 4.9 presents the characteristics of lesions identified during radiographic examination.

Table 4.9: Lesion Characteristics - Size, Location, and Radiographic Appearance

Category	**Frequency**	**Percentage (%)**
Lesion Size Lesion Size		
Not applicable/Not documented	237	89.8
6cm by 4cm	12	4.5
Others	15	5.7
Lesion Location		
Not applicable/Not documented	228	86.4
Maxilla	9	3.4
Mandible	6	2.3
Right mandible	6	2.3
Others	15	5.7
Radiographic Appearance (n=42)		
Radiolucent	27	64.3
Radioopaque	12	28.6
Mixed density	3	7.1
Lesion Border Definition (n=33)		
Well-defined	27	81.8
Irregular	6	18.2

Most cases did not have documented lesion sizes (89.8%, n=237) or locations (86.4%, n=228), as lesions were not present in the majority of radiographs. Among documented lesions, 6cm by 4cm was the most common size (4.5%, n=12), and the maxilla was the most frequently affected location (3.4%, n=9).

Radiographically, lesions appeared predominantly radiolucent (64.3%, n=27), with radioopaque lesions accounting for 28.6% (n=12) and mixed density lesions for 7.1% (n=3). The majority of lesions had well-defined borders (81.8%, n=27), while 18.2% (n=6) showed irregular borders.

4.5.4 Associated Features of Lesions

Table 4.10 shows the features associated with identified lesions.

Table 4.10: Distribution of Associated Features with Lesions

Associated Feature	Frequency	Percentage (%)
None/Not applicable	234	88.6
Facial distortion	12	4.5
Displaced tooth	3	1.1
Displaced upper tooth	3	1.1
Facial displacement	3	1.1
Root absorption and tooth displacement	3	1.1
Tooth displacement	3	1.1
Tooth displacement and root absorption	3	1.1
Total	**264**	**100.0**

The majority of cases (88.6%, n=234) had no associated features documented. Facial distortion was the most common associated feature at 4.5% (n=12), followed by various forms of tooth displacement and root absorption, each accounting for 1.1% (n=3) of cases.

4.6 Image Quality Assessment

Table 4.11 presents the assessment of diagnostic quality of the radiographic images.

Table 4.11: Distribution of Image Quality for Diagnostic Purposes

Image Quality Diagnostic	Frequency	Percentage (%)

Yes	259	98.9
No	3	1.1
Total	**262**	**100.0**

The vast majority of radiographic images were of diagnostic quality (98.9%, n=259), with only 1.1% (n=3) deemed non-diagnostic. This high rate indicates good technical quality control in radiographic procedures.

Diagnostic accuracy of radiological findings

Condition	**N**	**Sensitivity**	**Specificity**	**PPV**	**NPV**	**Accuracy**
Dental Pathology	105	87.7	83.3	94.7	66.7	86.7
Trauma/Fracture	36	100	100	100	100	100
Tumor/Lesion	226	100	96.9	84.6	100	97.3

4.5 Discussion of Findings

The findings from this study present a comprehensive profile of radiographic findings in the maxillofacial region based on analysis of 264 dental radiographic records from the University of Benin Teaching Hospital over the one-year period from January 2024 to January 2025. The results are discussed in relation to existing literature to identify convergences, divergences, and implications for clinical practice.

Sociodemographic Characteristics and Age Distribution

The study population was predominantly composed of young to middle-aged adults, with the 25-35 years age group constituting 43.6% of the sample, followed by 18-25 years (26.1%) and 35-45 years (24.6%). This concentration in younger age brackets aligns with established epidemiological patterns documented by Motamedi (2003), who noted that maxillofacial fractures and dental pathologies requiring radiographic intervention are more prevalent in economically active populations. The minimal representation of older age groups (45-65 years: 5.7%) diverges from epidemiological expectations and may reflect either true differences in disease prevalence in this regional setting or potential healthcare access disparities affecting older populations in tertiary facilities.

The slight female predominance (52.7% versus 47.3% male) differs from epidemiological literature on maxillofacial trauma, where male predominance is well-established. According to Motamedi (2003) and Shah & Bansal (2017), young males aged 16-30 years represent the highest-risk group for maxillofacial injuries. However, this gender distribution in the current study is explained by the diverse clinical presentations in a tertiary facility where non-trauma pathologies such as orthodontic assessments and routine check-ups constitute substantial portions of radiographic requests, and these conditions show more balanced or female-predominant gender distributions compared to trauma cases.

Clinical Indications for Radiographic Examination

Pain emerged as the predominant reason for radiographic examination (57.2%), aligning perfectly with established diagnostic protocols. According to Iannucci & Howerton (2016), dental radiography serves as an essential adjunctive tool in symptomatic dental presentations to identify underlying pathology not evident on clinical examination alone. This finding is consistent with clinical practice guidelines emphasizing symptom-driven and risk-based radiographic selection (American Dental Association, 2012).

Orthodontic purposes represented the second major indication (20.1%), reflecting the hospital's comprehensive role in dental care. Tumor evaluation (12.5%) and trauma/infection/routine check-up combined presentations (5.7%) demonstrate the multifaceted clinical applications of maxillofacial radiography. These findings align with literature by Boeddinghaus & Whyte (2008), emphasizing that dental radiographs facilitate identification of traumas, tumors, and inflammatory conditions.

Radiographic Modality Selection and Imaging Technology

The predominance of periapical radiographs (59.4%) reflects clinical alignment with established evidence. According to Rushton et al. (1999), intraoral periapical radiographs are highly effective for assessing periapical lesions, caries, and periodontal bone loss, providing detailed views of tooth roots and surrounding bone—exactly the applications evident in this study's distribution. This demonstrates appropriate clinical application of imaging modality selection based on diagnostic needs.

The equal utilization of CT (12.6%) and panoramic radiographs (12.6%) demonstrates the facility's advanced imaging capacity. Panoramic radiographs, according to Vandenberghe et al. (2012), are valuable for assessing third molar impactions, jaw fractures, and temporomandibular joint disorders, providing comprehensive views of the entire maxillofacial region. The utilization of CT reflects capability for enhanced visualization of complex pathologies, consistent with Pauwels et al. (2016), who emphasized CBCT's superior diagnostic capabilities for complex cases involving impacted teeth, endodontic complications, and implant planning.

Notably, all imaging was performed using digital modality (100%), representing complete implementation of modern radiographic standards. This aligns with Johnson (2008), who documented that digital radiography offers significant advantages over traditional film-based methods, including reduced radiation exposure, enhanced image manipulation, and immediate image availability. The current finding suggests institutional commitment to contemporary standards with improved diagnostic capability and radiation safety.

Clinical Findings: Prevalence of Dental Caries and Periapical Pathology

Among documented clinical findings, dental caries represented 22.7% of cases. When considering all cases containing root canal treatments (8.0% with caries and root canal treatments, plus additional combined presentations), caries-related pathology affected approximately 37.7% of documented cases. This substantial prevalence aligns with empirical literature on radiographic caries assessment. Berkhout (2015), in a meta-analysis of 58 studies analyzing over 20,000 tooth surfaces, reported bitewing radiographs achieved a pooled sensitivity of 0.77 for dentin lesions and 0.81 for specificity, demonstrating the clinical significance and radiographic detectability of caries in dental populations.

Irreversible pulpitis emerged as the most common pulpal diagnosis (17.0%), consistent with clinical expectations for symptomatic patient presentations. Hood (2023) confirmed that irreversible pulpitis commonly manifests as acute symptoms necessitating radiographic assessment to evaluate periapical status and guide endodontic treatment decisions. The finding aligns with the clinical reality that symptomatic patients seek radiographic evaluation at tertiary facilities.

Impacted Teeth and Developmental Anomalies

Among 69 cases involving tooth impaction, horizontal impaction (79.7%) predominated, followed by vertical impaction (15.9%). Motamedi (2003) documented that horizontal positioning of impacted teeth creates greater biomechanical stress during eruption and surgical extraction, validating the distribution observed in this study. This finding aligns with established epidemiological patterns of third molar impaction.

The identification of impacted teeth (6.4% of all diagnoses) reflects the established screening role of radiography. In comparison, Namdar Pekiner et al. (2021) reported impacted teeth at 15.78% in a study of 500 panoramic radiographs from children aged 2-14 years. The lower percentage in the current study is expected, as the population was predominantly older adults (18-65 years) where permanent tooth eruption is largely complete, resulting in fewer eruption-related anomalies.

Periapical Findings and Lesion Characteristics

Coronal radiolucency communicating with the pulp (17.0%) represented the most frequently documented periapical finding. Kirkevang et al. (2007) established that periapical radiographs can identify radiolucencies associated with apical periodontitis, with sensitivity of 0.65 and specificity of 0.90 for detecting periapical pathology. The current study's documentation of periapical findings aligns with and validates these established diagnostic capabilities.

The predominance of radiolucent lesions (64.3%) over radioopaque lesions (28.6%) suggests a higher prevalence of destructive bone pathologies compared to sclerotic or ossifying conditions. MacDonald (2020) documented that radiolucencies typically indicate inflammatory or cystic pathologies, while radioopaque lesions suggest ossifying or sclerotic processes. This distribution in the current study suggests a clinical population with a relatively higher burden of inflammatory or neoplastic pathology.

Well-defined lesion borders (81.8%) typically indicate chronic, slow-growing pathologies such as odontogenic cysts or residual lesions. Rozylo-Kalinowska (2020) confirmed that well-defined borders in periapical radiographs often characterize benign, chronic lesions, while inflammatory or acute processes produce irregular, ill-defined borders. This finding in the current study supports predominantly chronic pathological processes and validates clinical management algorithms where lesion characteristics guide diagnostic specificity and treatment urgency.

Cysts, Tumors, and Pathological Findings

The 15.7% prevalence of cysts or tumors identified radiographically represents a significant screening finding with important clinical implications. This aligns closely with literature documenting incidental pathological findings in archival radiographic studies. Namdar Pekiner et al. (2021) reported incidental lesions in 14.4% of cases in a study of 500 panoramic radiographs from pediatric patients, with apical ostitis (35.52%), impacted teeth (15.78%), and follicular cysts (9.21%) as most common findings. The prevalence in the current study is remarkably comparable, suggesting consistent radiographic yield across different populations and justifying radiographic screening protocols.

The identified malignancies, including squamous cell carcinoma (2.2%), parotid gland tumor (1.1%), and maxillary tumor (1.1%), represent 4.4% of the total sample. These findings highlight the critical screening function of radiographic imaging. Boeddinghaus & Whyte (2008) emphasized that dental radiographs facilitate identification of cysts and tumors, essential for early diagnosis and appropriate referral. The current detection of malignancies underscores the importance of comprehensive radiographic interpretation in identifying potentially serious pathologies requiring urgent specialist consultation.

Image Quality and Diagnostic Accuracy

The exceptional rate of diagnostic quality radiographs (98.9%) reflects rigorous technical quality control in the department, aligning with clinical standards and best practice recommendations. The diagnostic accuracy parameters demonstrated substantial diagnostic value: sensitivity for dental pathology (87.7%), specificity (83.3%), and accuracy (86.7%) align closely with literature on radiographic diagnostic performance. Ng et al. (2011), in a systematic review of 22 studies on periapical radiographs for detecting periapical pathology, documented sensitivity of 0.65 and specificity of 0.90 for detecting apical periodontitis—values comparable to and validating the current study's findings.

The perfect accuracy for trauma/fracture detection (100% sensitivity and specificity) represents an important finding but must be interpreted within context. Zhou et al. (2021), in a systematic review of panoramic radiography in maxillofacial trauma, reported sensitivity of 85% for mandibular fractures and 60-70% for midfacial fractures, with documented false negatives for non-displaced fractures. The perfect accuracy in the current study may reflect facility-specific excellence in trauma imaging protocols or potential selection bias where predominantly obvious, displaced fractures were included in the analysis.

The high accuracy for tumor/lesion detection (97.3%) represents excellent performance. Pauwels et al. (2016) documented that CBCT provides superior detection compared to conventional radiography, suggesting that the current study's high values reflect either the facility's specific expertise in lesion interpretation or confirmation bias if lesion diagnoses were subsequently verified by advanced imaging modalities.

Divergences from Literature and Their Implications

CHAPTER FIVE

CONCLUSION, RECOMMENDATIONS AND SUGGESTIONS FOR FURTHER STUDIES

5.1 Conclusion

This retrospective analysis of 264 dental radiographic records from the University of Benin Teaching Hospital has provided comprehensive insights into radiographic findings, diagnostic capabilities, and the clinical burden of maxillofacial region pathologies within a Nigerian tertiary healthcare facility. The study demonstrates that dental radiographs, when appropriately selected and interpreted, remain highly effective diagnostic tools with sensitivity, specificity, and accuracy rates ranging from 83.3-100%, particularly for detecting dental pathologies, trauma-related fractures, and maxillofacial lesions.

The study population was predominantly composed of young to middle-aged adults (43.6% aged 25-35 years) presenting primarily with pain (57.2%), for which radiographic imaging identified significant pathology in approximately 44.3% of cases with documented clinical findings. Dental caries and irreversible pulpitis emerged as the most prevalent clinical and pulpal diagnoses, reflecting substantial burden of dental disease in the study population. The identification of 39 cysts or tumors (15.7% prevalence) among examined radiographs, including cases of squamous cell carcinoma (2.2%) and ameloblastoma (1.1%), underscores the critical screening function of routine radiographic imaging in early detection of potentially serious pathologies requiring specialist referral and intervention.

The utilization of diverse radiographic modalities—dominated by periapical radiographs (59.4%) but including panoramic (12.6%) and cross-sectional imaging (12.6%)—reflects clinically appropriate selection of imaging techniques based on diagnostic needs and anatomical considerations. The universal implementation of digital radiographic systems (100% of cases) demonstrates institutional commitment to contemporary radiographic standards, enabling enhanced image quality, reduced radiation exposure, and potential for future artificial intelligence-assisted diagnostic applications.

The 98.9% rate of diagnostic quality radiographs indicates effective quality assurance protocols and appropriately trained personnel, essential prerequisites for reliable radiographic interpretation. The diagnostic accuracy findings validate the diagnostic utility of dental radiographs for maxillofacial assessment while acknowledging inherent two-dimensional limitations, which may necessitate supplementary three-dimensional imaging in complex or clinically indeterminate cases. Overall, this study reaffirms the essential role of dental radiographs in modern maxillofacial diagnostic practice while identifying specific institutional patterns and opportunities for continued quality improvement.

5.2 Recommendations

Based on the findings and conclusions of this study, the following recommendations are offered to improve radiographic practice, patient outcomes, and professional standards:

1. Continue prioritizing appropriate modality selection based on clinical indication and anatomical considerations, with periapical radiographs serving as first-line imaging for localized pathology and panoramic radiographs utilized for comprehensive maxillofacial screening.
2. Develop institutional protocols for selective integration of cone-beam computed tomography (CBCT) for complex cases, particularly those involving suspected impacted teeth, non-displaced fractures, temporomandibular joint pathology, or lesions where three-dimensional assessment significantly impacts treatment planning.

3. Establish risk-based radiographic screening protocols that balance diagnostic benefit with radiation safety, particularly for pediatric and young adult populations where lifetime risk from cumulative radiation exposure is greatest.
4. Provide continuing education programs in radiographic interpretation with emphasis on recognizing pathological patterns, avoiding common diagnostic errors, and appropriate modality selection based on clinical presentations.
5. Conduct periodic inter-observer reliability studies to assess consistency among interpreters and identify individuals requiring additional training in specific diagnostic domains.

5.3 Limitations of the Study

While this study provides valuable insights into radiographic findings in a tertiary healthcare setting, several limitations should be acknowledged:

1. **Retrospective Design:** The retrospective nature limited standardization of clinical information gathering and radiographic protocols. Clinical indications and findings were recorded by multiple clinicians using varying documentation standards, potentially introducing inconsistency in data quality and completeness.
2. **Incomplete Documentation:** Substantial portions of records (55.7% for clinical findings and 33% for pulpal/periodontal diagnosis) lacked documented findings, limiting comprehensive analysis and potentially introducing selection bias toward more severe or obvious pathologies more likely to be documented.
3. **Single Institution:** Data derived exclusively from University of Benin Teaching Hospital, a tertiary facility with potentially different patient demographics, disease patterns, and radiographic capabilities compared to primary or secondary healthcare settings, limiting generalizability to broader Nigerian populations or different healthcare systems.

4. **One-Year Timeframe:** The 12-month collection period (January 2024-January 2025) may not fully capture seasonal variations or long-term trends in radiographic findings and clinical presentations.

5. **Limited Demographic Data:** Information on relevant demographic variables such as socioeconomic status, oral hygiene practices, diet, smoking history, and systemic health conditions was not available, preventing analysis of factors associated with radiographic findings and disease prevalence.
6. **Two-Dimensional Imaging Limitation:** The predominance of conventional two-dimensional radiographs (intraoral and panoramic) limits assessment of buccolingual dimensions and may underestimate lesion extent compared to three-dimensional modalities like CBCT.
7. **Inter-Observer Variability:** While quality radiographs were produced, formal inter-observer or intra-observer reliability assessments were not conducted for the primary data collection process, potentially introducing interpretation bias.

5.4 Suggestions for Further Studies

To address identified limitations and expand understanding of radiographic findings in maxillofacial assessment, the following areas warrant further investigation:

1. Conduct prospective cohort studies with standardized data collection protocols and quality control measures to ensure completeness and consistency of information, enabling robust analysis of associations between radiographic findings and clinical outcomes.

2. Implement multi-center studies comparing radiographic findings and diagnostic patterns across diverse healthcare settings (primary, secondary, and tertiary facilities) to establish population-specific prevalence estimates and assess generalizability across Nigeria.
3. Establish longitudinal follow-up studies tracking radiographic findings over extended periods (3-5 years) to assess disease progression, treatment outcomes, and clinical impacts of radiographic diagnoses on patient management.
4. Conduct comparative effectiveness studies examining diagnostic accuracy of conventional two-dimensional radiographs versus cone-beam computed tomography for complex cases, establishing evidence-based criteria for three-dimensional imaging utilization.
5. Investigate relationships between socioeconomic factors, access to dental care, oral health practices, and radiographically documented pathologies to identify health disparities and inform targeted interventions.
6. Evaluate integration of radiographic findings with electronic health records and clinical decision support systems to optimize diagnostic workflows and improve clinical outcomes.

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