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Oral and maxillofacial radiology in orthodontics

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Abstract

Oral and maxillofacial radiology is a pivotal component of orthodontics, providing essential imaging that aids in the diagnosis and treatment planning of dental and skeletal conditions. This article examines various radiographic techniques, including panoramic radiography, lateral cephalometric radiographs, and cone-beam computed tomography (CBCT), emphasizing their roles in diagnosing dental anomalies and assessing the jaw's structure. It discusses the significance of accurate imaging for understanding patient conditions and planning effective orthodontic interventions. Safety considerations regarding radiation exposure, particularly in younger patients, are addressed, alongside the importance of adhering to the ALARA (As Low as Reasonably Achievable) principle. As advancements in technology continue to shape the field, the integration of digital imaging and artificial intelligence is highlighted as a transformative force in orthodontic practice, enhancing diagnostic accuracy and treatment outcomes. This review underscores the critical role of oral and maxillofacial radiology in orthodontics and its ongoing evolution in response to technological advancements. This abstract summarizes the key points of the article, highlighting its focus and significance in the field of orthodontics.

Keywords: Oral Radiology; Maxillofacial Radiology; Orthodontics; Radiographic Techniques

1. Introduction

Oral and maxillofacial radiology is an indispensable component of orthodontic practice, offering critical insights that aid in diagnosing and managing various dental and skeletal conditions. Radiological imaging enables orthodontists to visualize the intricate anatomy of the jaws, teeth, and surrounding structures, facilitating informed treatment decisions (García et al., 2021). The use of advanced imaging techniques has transformed the landscape of orthodontics, enhancing the accuracy of diagnoses and the efficacy of treatment planning (Haas et al., 2020). Orthodontics primarily focuses on correcting dental and facial irregularities, which often necessitate a comprehensive understanding of the underlying anatomical structures. Conventional radiographic techniques, such as intraoral periapical and bitewing radiographs, provide valuable information about individual teeth and their surrounding bone structures. However, these methods may lack

the depth and detail required for complex cases involving the maxillofacial region (Kanzaki et al., 2019). Consequently, the advent of more sophisticated imaging modalities, such as panoramic radiography and cone-beam computed tomography (CBCT), has been pivotal in enhancing diagnostic capabilities within orthodontics.

Panoramic radiography is widely used in orthodontic practices for its ability to provide a comprehensive view of the entire dental arch and surrounding anatomical structures in a single image. This technique is invaluable for assessing dental relationships, identifying impacted teeth, and detecting jaw lesions (Ludlow & Ivanovic, 2008). However, while

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panoramic images are beneficial for an overview, they may not offer the three-dimensional insights necessary for detailed evaluations. This limitation has led to the increased adoption of CBCT, which provides high- resolution three-dimensional images of the maxillofacial region, allowing for precise assessments of bone morphology and tooth position (Scarfe et al., 2008). The integration of digital imaging techniques in orthodontics has also significantly improved the workflow and outcomes of orthodontic treatments. Digital radiography offers advantages such as reduced radiation exposure, enhanced image quality, and the ability to manipulate images for better analysis (Meyer et al., 2020). Furthermore, the incorporation of artificial intelligence (AI) in image analysis is an emerging trend that promises to enhance diagnostic accuracy and efficiency, potentially revolutionizing orthodontic practices (Hossain et al., 2021).

Despite the numerous benefits of radiographic imaging in orthodontics, safety considerations regarding radiation exposure remain a paramount concern, particularly for pediatric patients. The ALARA (As Low As Reasonably Achievable) principle emphasizes minimizing radiation exposure while obtaining necessary diagnostic information (Brenner & Hall, 2007). Thus, understanding the appropriate indications for each imaging modality is crucial in ensuring patient safety without compromising diagnostic quality. In summary, oral and maxillofacial radiology is fundamental to orthodontics, providing essential diagnostic information that informs treatment planning and patient management. As technology continues to advance, the field of orthodontics is poised to benefit from improved imaging techniques and innovative approaches, enhancing the quality of care provided to patients. This article will delve deeper into the various radiographic techniques employed in orthodontics, their implications for practice, and the ongoing advancements in the field.

1.1. The Importance of Radiological Imaging in Orthodontic Diagnosis and Treatment Planning

Radiological imaging is a fundamental aspect of orthodontic practice, playing an essential role in the diagnosis and treatment planning phases of orthodontic care. Accurate imaging allows orthodontists to obtain critical information about dental and skeletal structures, facilitating effective treatment decisions that are tailored to each patient's unique anatomy (Haas et al., 2020). The integration of various imaging modalities has transformed orthodontic practice, enhanced diagnostic accuracy and improving treatment outcomes. One of the primary benefits of radiological imaging in orthodontics is its ability to identify and evaluate dental and skeletal anomalies. Conventional two-dimensional imaging techniques, such as panoramic radiographs, provide a broad view of the dental arches and surrounding structures, which helps in detecting conditions such as impacted teeth, agenesis, and other developmental anomalies (Ludlow & Ivanovic, 2008). Panoramic imaging offers a comprehensive overview that is crucial for initial diagnosis and treatment planning, allowing orthodontists to assess the positioning and development of teeth in relation to the jaw and surrounding anatomical features (Kanzaki et al., 2019).

In addition to panoramic imaging, lateral cephalometric radiographs are vital for evaluating craniofacial relationships. This type of imaging allows orthodontists to analyze skeletal relationships, determine growth patterns, and assess cephalometric measurements that are essential for diagnosing malocclusions and planning appropriate treatment approaches (Hossain et al., 2021). Cephalometric analysis not only aids in diagnosing existing conditions but also helps in predicting future growth, which is critical for treatment success in growing patients. The introduction of cone-beam computed tomography (CBCT) has revolutionized the field of orthodontics by providing three-dimensional images that allow for more detailed assessments of dental and skeletal structures. CBCT enables orthodontists to visualize the spatial relationships of teeth, roots, and surrounding anatomical landmarks in a way that traditional two-dimensional images cannot (Scarfe et al., 2008). This advanced imaging technology is particularly beneficial for diagnosing complex cases, such as those involving impacted teeth or assessing the need for surgical intervention. By offering a clearer view of the three-dimensional anatomy, CBCT enhances the orthodontist's ability to develop precise and individualized treatment plans. Radiological imaging also plays a significant role in monitoring treatment progress. Regular radiographic evaluations allow orthodontists to track tooth movement and assess the effectiveness of the applied forces during treatment (Meyer et al., 2020). For example, periodic imaging can help identify any deviations from the expected treatment outcomes, enabling clinicians to make timely adjustments to the treatment plan. This proactive approach to monitoring ensures that patients receive the most effective care, ultimately improving treatment efficiency and reducing overall treatment time.

Moreover, effective communication with patients and their families is another important aspect of radiological imaging. High-quality images can serve as valuable educational tools, allowing orthodontists to explain complex anatomical relationships and treatment options more clearly (García et al., 2021). By providing visual aids, orthodontists can foster better understanding and engagement, which is crucial for patient compliance and satisfaction. Despite the many advantages of radiological imaging, it is essential to consider the safety aspects associated with radiation exposure. Adhering to the ALARA (As Low As Reasonably Achievable) principle is critical in minimizing radiation exposure to patients, particularly children who are more sensitive to radiation effects (Brenner & Hall, 2007). Orthodontists must exercise clinical judgment in selecting the most appropriate imaging modalities based on the specific diagnostic needs while ensuring that patient safety remains a top priority.

In conclusion, radiological imaging is indispensable in orthodontic diagnosis and treatment planning, providing essential information for accurate assessment and tailored treatment strategies. The integration of advanced imaging technologies, particularly CBCT, has significantly enhanced the orthodontic practice, allowing for more precise diagnosis and improved patient outcomes. As the field continues to evolve with technological advancements, the importance of radiological imaging in orthodontics will only grow, ensuring that orthodontists can deliver the highest quality of care to their patients.

2. Literature review

- Several studies in recent years have examined the role and significance of radiological imaging of the oral, maxillofacial, and facial structures in orthodontics. These studies have focused on various imaging techniques and how they improve diagnosis and treatment planning in orthodontics.
- Study by Bjork and Skieller (1983): A study by Bjork and Skieller, titled “Growth of the Maxilla in Three Dimensions as Revealed Radiographically by the Implant Method”, was conducted in 1983. This research utilized panoramic radiography to examine the growth patterns of the maxilla and its relationship to surrounding structures. The findings indicated that radiography could accurately track growth changes over time, aiding in a deeper understanding of maxillary growth patterns, essential for orthodontic treatment planning.
- Research by Ludlow and Ivanovic (2008): In 2008, Ludlow and Ivanovic conducted a study titled “Comparative Radiology: Panoramic Versus Cone-Beam Computed Tomography (CBCT)”. This research compared the accuracy and detail provided by two different imaging methods. Results showed that CBCT offered more precise three-dimensional images of dental and skeletal structures than traditional two-dimensional radiography and is recommended for complex cases.
- Study by Brenner and Hall (2007): Brenner and Hall conducted a study in 2007 titled “Computed Tomography—An Increasing Source of Radiation Exposure”, which addressed the risks associated with radiation exposure in dental imaging, especially in children. This study emphasized the importance of the ALARA principle (As Low As Reasonably Achievable), concluding that CBCT and other high-radiation techniques should be limited to necessary cases to minimize radiation risks to patient health.
- Research by Hossain et al. (2021): In 2021, Hossain and colleagues conducted a study titled “The Role of Artificial Intelligence in Dental Imaging”, exploring AI’s applications in analyzing radiological images in orthodontics. The findings revealed that AI algorithms could assist in automating cephalometric analyses, facilitating diagnosis and treatment planning.

2.1. The Role of Radiological Imaging in Orthodontic Diagnosis and Treatment Planning

Radiological imaging plays a crucial role in modern orthodontics, providing essential insights into the structures and relationships of the teeth, jaws, and craniofacial regions. This imaging enables orthodontists to accurately diagnose malocclusions, identify underlying skeletal and dental issues, and plan individualized treatments (Kapila & Conley, 2011). Radiological techniques, such as panoramic radiography, cephalometry, and cone-beam computed tomography (CBCT), each serve specific diagnostic purposes and offer varying degrees of precision and detail that are pivotal in treatment planning.

2.2. Diagnostic Applications

Radiological imaging allows orthodontists to comprehensively analyze occlusal and skeletal abnormalities. For instance, cephalometric analysis, a widely used radiographic technique, provides critical information about the anteroposterior and vertical relationships of the jaws. Studies have shown that cephalometry is instrumental in identifying skeletal discrepancies and classifying malocclusions, such as Class II or Class III jaw relationships, thus guiding the orthodontic approach (Jacobson & Jacobson, 2006). Similarly, panoramic radiography, with its ability to capture a wide image of the dental arches and surrounding structures, is frequently used to detect impacted teeth, supernumerary teeth, and other structural anomalies, which can significantly impact treatment planning (White & Pharoah, 2014).

2.3. Treatment Planning

Radiological imaging is essential for creating accurate treatment plans tailored to each patient’s needs. CBCT, in particular, has been transformative in orthodontics due to its three-dimensional imaging capabilities. This modality allows for more precise visualization of the tooth roots, jaw bone morphology, and temporomandibular joint (TMJ) structures. CBCT's ability to provide cross-sectional images has been invaluable in diagnosing conditions like impacted canines, root resorption, and other complex conditions that may affect treatment choices (Kapila & Conley, 2011). For example, studies have indicated that CBCT is especially useful for locating impacted canines, facilitating surgical planning, and minimizing risks to adjacent teeth (Alqerban et al., 2009).

2.4. Monitoring Treatment Progress and Outcomes

Radiological imaging also plays a vital role in monitoring progress and assessing treatment outcomes. During the course of orthodontic treatment, imaging is often used to evaluate the alignment and movement of teeth, ensuring that the treatment objectives are being met. This is especially critical in complex cases, where tracking root positioning and bone changes over time can prevent adverse outcomes, such as root resorption or bone loss (Molen, 2010). For instance, panoramic radiography and cephalometry are commonly used to assess progress during treatment, while CBCT may be used selectively for detailed post-treatment evaluations, particularly in cases requiring surgical interventions or jaw realignment (Silva et al., 2015).

2.5. Emerging Technologies and Personalized Treatment

Emerging imaging technologies, such as digital cephalometry and artificial intelligence (AI)- assisted analysis, are enhancing the role of radiological imaging in orthodontics. AI-powered tools can now assist in automating cephalometric tracing, detecting malocclusions, and even predicting growth patterns based on imaging data, thus supporting more personalized and efficient treatment planning (Hossain et al., 2021). These advancements underscore the increasing reliance on radiology in orthodontics as a foundational tool for creating precise and patient-specific treatment plans.

3. Understanding the Standards for Obtaining Cephalometric and Panoramic Radiographs Using Analog and Digital Methods

Cephalometric and panoramic radiographs serve as essential tools in the diagnosis and treatment of orthodontic issues, playing a critical role in evaluating dental and skeletal structures. Adhering to specific standards in the acquisition of these images improves their quality and accuracy, ultimately leading to more precise treatment planning. In this section, we will discuss the standards for obtaining cephalometric and panoramic radiographs using both analog and digital methods.

3.1. Standards for Obtaining Cephalometric Radiographs

Cephalometric radiography provides two-dimensional images of the facial and dental structures, allowing orthodontists to analyze the spatial relationships between these structures. The following standards must be adhered to:

- Patient Positioning: The patient must be positioned correctly to minimize distortion. The head should be aligned perpendicular to a reference plane, and this alignment can be achieved through the use of specific markings and leveling instruments. Research indicates that failing to adhere to this standard can lead to significant diagnostic errors (Moyers et al., 2005).
- Beam Alignment: The radiographic beam must be precisely aligned at an appropriate angle relative to the horizontal plane. This angle typically ranges from 0 to 8 degrees and may vary depending on the type of image and the purpose of the radiography. Accurate beam alignment contributes to reducing distortion and enhancing image quality (Bishara & Bishara, 2010).
- Source-to-Patient Distance: The distance between the radiation source and the patient should generally be set between 150 to 200 centimeters. This distance helps minimize unnecessary radiation exposure to the patient and enhances image quality. Using appropriate filters can further assist in reducing exposure (McNamara, 1984).

3.2. Standards for Obtaining Panoramic Radiographs

Panoramic radiography is a key method for imaging the dental arch and surrounding structures, requiring adherence to specific standards:

- Patient Positioning: The patient should be positioned correctly while sitting or standing, maintaining their head in line with the horizontal plane. This positioning is crucial to prevent image distortion and to preserve accurate relationships between structures (Hägg et al., 1995). Additionally, the patient must remain still during the image acquisition process.

- Device Settings: The panoramic radiography device must be precisely calibrated. The radiation intensity, exposure time, and type of filters should be correctly adjusted to obtain high-quality images that can be accurately interpreted. Exposure times typically range from 10 to 20 seconds, varying depending on the device and patient characteristics (Bai et al., 2019).
- Safety Protocols: Adhering to safety protocols to minimize radiation exposure to the patient is paramount. Using appropriate filters and shields and reducing exposure time are among these safety measures. According to Kakadiya et al. (2018), educating patients and staff about safety procedures can significantly mitigate the risks associated with radiation exposure.

3.3. Digital Imaging Methods in Radiology

Digital radiography is increasingly gaining popularity due to its numerous advantages, significantly streamlining the imaging process and enhancing image quality. Key benefits of digital methods include:

- Image Quality: Digital radiography typically provides higher quality images than analog methods. Digital images are captured with high-resolution sensors and processed using advanced software, resulting in images with enhanced clarity and magnification capabilities, allowing for more precise analysis (Hassani et al., 2018). Additionally, digital images are generally easier to store and retrieve.
- Data Management: Digital images can be easily stored, shared, and managed. This facilitates quick access to patient records and straightforward updates to information. The use of Picture Archiving and Communication Systems (PACS) can also optimize image management and enhance clinic efficiency (Kakadiya et al., 2018). These systems allow practitioners to rapidly retrieve images for consultations and treatment planning.

3.4. Comparison of Analog and Digital Standards

While both analog and digital methods have their own specific standards, the digital approach is increasingly favored due to its speed, quality, and enhanced capabilities. For instance, in digital methods, image processing occurs automatically, significantly reducing the waiting time for image acquisition. Moreover, the ability to adjust brightness and contrast in digital images allows for a more accurate assessment of dental and skeletal structures (Sharma et al., 2018).

3.5. Safety and Ethical Considerations

3.5.1. Observing safety protocols in both imaging methods (analog and digital) is critically important:

- Reducing Radiation Exposure: Adhering to the principle of ALARA (As Low As Reasonably Achievable) in radiation exposure, along with utilizing protective techniques, can help minimize the adverse effects of radiation exposure. This is particularly important for patients requiring frequent radiographic evaluations.
- Staff Training: Training personnel on safety protocols and best imaging practices is crucial for safeguarding patient health and reducing potential errors. These training sessions should include familiarization with equipment, correct patient positioning, and safety protocols.

In conclusion, understanding and adhering to the standards for obtaining cephalometric and panoramic radiographs using both analog and digital methods is essential for accurate diagnosis, treatment planning, and management of complications. With advancements in technology, particularly in digital imaging, orthodontists are better equipped to provide enhanced care to their patients. Improvements in technology and awareness of standard protocols enable practitioners to deliver the highest quality of services to their patients.

4. The advantages and disadvantages of digital radiography

One significant advantage of digital radiography is the superior image quality it provides. Digital systems typically produce images with higher resolution and enhanced detail, allowing for more precise diagnosis of orthodontic conditions. This improved clarity can facilitate better treatment planning and monitoring of patient progress over time (Schwartz et al., 2015). Moreover, digital images can be easily manipulated to enhance visibility of certain structures, which can be particularly beneficial in complex cases. Another notable benefit of digital radiography is the reduction in radiation dose. Digital imaging systems require significantly less radiation exposure compared to traditional analog methods. This reduction is vital for patient safety, especially for children and adolescents who are more sensitive to radiation (Mäkitie et al., 2019). Lower radiation doses also align with the principle of ALARA (As Low As Reasonably Achievable), which is essential in dental radiography.

The speed of image acquisition and processing is another key advantage of digital radiography. Images are available almost instantaneously after being captured, allowing orthodontists to quickly review and interpret the findings. This rapid turnaround can significantly enhance the efficiency of clinical workflows, enabling faster decision-making and treatment initiation (Araujo et al., 2016). Additionally, digital images can be easily stored and retrieved, streamlining record-keeping and patient management. Digital radiography also offers the convenience of easy editing and sharing of images. Orthodontists can annotate, adjust brightness, or contrast, and highlight specific areas of interest within the images. This feature allows for more effective communication with colleagues and specialists, improving collaborative efforts in complex cases (Ghaffari et al., 2021). Furthermore, the ability to share images electronically facilitates remote consultations and second opinions, broadening access to expert advice.

In terms of cost, although the initial investment in digital radiography equipment can be substantial, the long-term savings may be significant. The elimination of film, processing chemicals, and storage materials can reduce ongoing operational costs. Additionally, the decreased need for retakes due to improved image quality can lead to further savings (Jiang et al., 2018). Despite these advantages, there are also several disadvantages associated with digital radiography. One major drawback is the high initial cost of purchasing and installing digital imaging systems. This upfront investment may deter some practices, particularly smaller clinics with limited budgets, from transitioning to digital technology (Kumar & Shyam, 2017). Furthermore,

implementing digital radiography requires specialized training for personnel. Staff members need to be educated not only on how to operate the equipment but also on how to interpret digital images effectively. This training process can be time-consuming and may temporarily disrupt workflow (Kraus et al., 2020). Security and privacy concerns are also pertinent in the digital age. The storage and transmission of digital images can pose risks regarding patient confidentiality and data security. Dental practices must implement robust cybersecurity measures to protect sensitive information from potential breaches (Drescher et al., 2019). Compliance with regulations such as HIPAA (Health Insurance Portability and Accountability Act) in the United States adds an additional layer of complexity to managing digital patient records. Lastly, there are technological limitations that should be acknowledged. Some specific imaging techniques or nuances may not be as effectively executed with digital systems compared to traditional methods. Continuous advancements in technology are required to overcome these limitations and fully realize the potential of digital radiography in orthodontics (Nawrocka et al., 2021).

In summary, digital radiography presents numerous advantages, including enhanced image quality, reduced radiation exposure, and improved efficiency in clinical workflows. However, the high initial costs, training requirements, security concerns, and technological limitations are critical factors that practitioners must consider when adopting this technology.

4.1. Familiarization with Radiographic Methods for Evaluating TMJ and Their Interpretation

The temporomandibular joint (TMJ) is one of the most complex joints in the human body, playing a crucial role in jaw movement and daily activities such as chewing and speaking. Disorders of this joint can have profound effects on individuals' quality of life. Therefore, a thorough examination of the TMJ is of great importance. In this regard, there are various radiographic methods, each with its specific features and advantages. The following sections will explore and interpret four common radiographic methods, including arthrography, tomography, MRI, and CT scan.

4.1.1. Arthrography

Arthrography is an imaging method that aids in the examination and assessment of the inside of the TMJ. In this technique, a contrast medium is injected into the joint space. This contrast, typically a non-volatile substance, clearly reveals the internal structures of the joint, allowing for

a detailed view of the articular disc, ligaments, and joint space. Arthrography can be performed in two forms: digital arthrography and analog arthrography. Digital arthrography employs more advanced technologies and provides higher-quality images. This method is particularly effective for patients with clear symptoms of TMJ disorders, such as pain and movement issues in the jaw. The method has advantages, including high accuracy in diagnosing disc disorders and tissue injuries and the ability to examine the internal structures of the joint in detail (Korkmaz et al., 2019). Additionally, the results of arthrography are quickly accessible. However, the need for contrast injection, which may be uncomfortable for some patients, is a disadvantage of this method. The risk of infection or complications from the injection and the high costs of the digital method are also other drawbacks.

Interpretation: In interpreting arthrographic images, physicians evaluate the position of the articular disc. Under normal conditions, the disc should be in its correct position when the mouth is opened and closed. Disc displacement, especially anterior disc displacement in the closed position, can indicate joint disorders. Moreover, the presence of effusion is noted. The presence of excess fluid in the joint space can be a sign of inflammation or injury to the joint tissues. Arthrographic images can also assist in identifying tissue injuries and anatomical abnormalities (Korkmaz et al., 2019).

4.1.2. Tomography

Tomography is an imaging technique used to obtain cross-sectional images of the TMJ and surrounding structures. This method is typically employed to examine bony changes and structural problems of the joint. Tomography can be divided into two main types: axial tomography (X-ray) and computed tomography (CT). Tomography is especially useful for identifying and assessing fractures, bony abnormalities, and degenerative changes in the TMJ. This method can aid in a better understanding of the condition of the bones and soft tissues surrounding the joint. This technique has advantages such as the ability to accurately observe bony structures and identify small changes in the bones. Furthermore, precise analysis of the joint status and degenerative problems is another of its features (Al-Juboori et al., 2021). However, the disadvantages of this method include exposure to X-rays, which may raise concerns regarding long-term effects. Additionally, the inability to adequately assess soft tissues and the need for specialized equipment and high costs are other limitations.

Interpretation: In interpreting tomography images, physicians evaluate the relationships between the condyle (the head of the lower jaw bone), the glenoid fossa, and the articular eminence. Evidence such as the presence of osteophytes (bony outgrowths) and changes in the joint space may indicate the presence of arthritis or degenerative disorders. Additionally, erosion of the condylar surface or changes in bony tissue can assist in diagnosing problems such as fractures or developmental abnormalities. Tomography allows physicians to identify subtle changes in bony structures and achieve more precise evaluations (Al-Juboori et al., 2021).

4.1.3. MRI

Magnetic Resonance Imaging (MRI) is one of the best and most advanced imaging methods for evaluating the TMJ. This method is highly beneficial due to its ability to provide high-quality images of soft tissues, especially the articular disc. MRI can assist in examining the status of the soft tissues surrounding the TMJ, including ligaments, tendons, and muscles. This method is particularly effective in diagnosing soft tissue and degenerative problems such as disc disorders, inflammation, and damage to the surrounding joint tissues. Since MRI does not use X-rays, this method is a safe option for patients, especially in cases where repeated examinations are needed (Zhang et al., 2020). This feature has established MRI as a key tool in diagnosing and evaluating the TMJ. The advantages of MRI include the ability to provide detailed images of soft tissues and the absence of X-ray exposure. However, it also has limitations, such as the high cost of conducting this imaging and the time-consuming nature of the process. Additionally, in some cases, patients may be unable to use this method due to the presence of metal devices or cardiac pumps.

Interpretation: In interpreting MRI images, physicians pay attention to the position and shape of the articular disc. The disc should be in its correct position when the mouth is opened. If the disc is displaced anteriorly, posteriorly, or laterally, this indicates a dysfunction in TMJ performance. Physicians particularly examine the status of fluid in the joint, as the presence of excess fluid can be a sign of inflammation or infection. Additionally, MRI images can help identify tissue injuries and anatomical abnormalities (Zhang et al., 2020).

4.1.4. CT SCAN

CT scan is an advanced imaging method that aids in examining the bony and soft structures of the TMJ. This technique uses X-rays to produce cross-sectional images and allows for a precise view

of changes in bony structures. CT scan is particularly effective for assessing fractures, structural abnormalities, and bony changes in the TMJ. This method can also assist physicians in identifying significant bone injuries and analyzing the overall bone condition. The use of three-dimensional reconstructions in CT scans can enhance the understanding of spatial relationships among different TMJ structures and lead to more detailed examinations of the joint and its surrounding tissues (Liu et al., 2018). The advantages of CT scans include high accuracy in identifying injuries and the ability to perform three-dimensional analysis of TMJ structures. However, disadvantages of this method include exposure to X-rays and the high cost of the procedure. Additionally, compared to MRI, CT images usually provide lower quality in presenting soft tissue details.

Interpretation: In CT images, physicians examine the morphology of the condyle and the glenoid fossa. They look for changes in bony structures that may indicate the presence of arthritis, fractures, or structural abnormalities. Evidence such as deformation or reduction of bony volume can aid in diagnosing degenerative disorders and bone resorption (Liu et al., 2018).

In general, each of the radiographic methods for examining the TMJ has its specific features and limitations. The choice of the appropriate method depends on the clinical condition of the patient, the type of disorder, and diagnostic needs. Arthrography is useful for examining disc and soft tissue problems, tomography for analyzing bony changes, MRI for providing high-quality images of soft tissues, and CT scans for accurately assessing bony structures and their abnormalities. Understanding the advantages and disadvantages of each method helps physicians make better decisions regarding the diagnosis and treatment of TMJ disorders.

4.2. Definition of CBCT and Its Advantages in Orthodontics Definition of CBCT

Cone Beam Computed Tomography (CBCT) is an advanced imaging method specifically designed for dental applications, particularly in orthodontics. This technique utilizes a cone-shaped beam that rotates around the patient, enabling the production of three-dimensional images of dental and maxillofacial structures. Due to its high-quality images and unparalleled diagnostic accuracy, CBCT is considered a key tool in the assessment of dental and maxillofacial abnormalities (Ahlgren & Torkko, 2021). In the CBCT procedure, the patient is initially positioned either standing or sitting under the device. This device consists of an X-ray source and a detector that

rotate simultaneously around the patient's head. During this process, cone-shaped beams are directed at various points on the face, and images are collected from multiple angles. This data is then transferred to specialized software that processes the information to produce accurate two- dimensional and three-dimensional images of the areas of interest (Kamburoğlu & Günbay, 2018).

A key advantage of CBCT over traditional methods such as conventional CT scans and two- dimensional radiographs is its ability to produce highly precise three-dimensional images, which can aid in identifying more specific issues in teeth and jaw bones. This feature enables orthodontists to more accurately identify problems such as dental deviations, structural abnormalities, and temporomandibular joint (TMJ) issues. Furthermore, CBCT is typically associated with lower radiation exposure compared to traditional imaging techniques, which is especially important in treating young patients and individuals who require repeated imaging (Liu et al., 2018). This technique can also be utilized in complex treatments such as jaw surgeries, braces installation, and the design of bridges and crowns. Overall, CBCT serves as a key tool in orthodontics, assisting practitioners in making better treatment decisions based on more accurate information and improving the quality of care provided to patients (Kamburoğlu & Günbay, 2018).

4.3. Advantages and Disadvantages of CBCT in Orthodontics

CBCT has numerous advantages that make it an effective and efficient tool in orthodontics. One of the main advantages is the high accuracy of three-dimensional images, which helps in the precise diagnosis of dental issues and abnormalities. This accuracy is crucial in identifying anatomical anomalies, joint disorders, and dental diseases, allowing practitioners to easily analyze dental and maxillofacial structures (Ahlgren & Torkko, 2021). In addition, CBCT helps reduce the need for conventional radiographs. Since this method generally involves lower radiation exposure, it can contribute to patient safety by preventing them from being subjected to additional radiation. Therefore, CBCT is particularly considered a safe and appropriate choice for patients requiring frequent imaging (Liu et al., 2018). Another advantage of CBCT is its ability to provide precise analysis of the anatomical relationships between teeth, jaws, and other surrounding structures. This information can assist orthodontists in planning complex treatments and making better decisions for patient care. Additionally, CBCT enables practitioners to accurately identify dental issues such as asymmetry, tooth displacement, and structural abnormalities (Kamburoğlu & Günbay, 2018).

However, CBCT also has disadvantages that should be considered. One of the primary drawbacks is the high cost of the equipment and the imaging process, which may prevent some smaller practices and clinics from utilizing this technology. These costs can be particularly challenging for patients undergoing orthodontic treatments (Ahlgren & Torkko, 2021). Another issue to consider is radiation exposure. Although the radiation dose in CBCT is lower than that of conventional CT scans, there are still concerns about the long-term effects of radiation exposure on health. Practitioners need to carefully weigh the risks and benefits of using CBCT, especially for young patients and those requiring repeated imaging (Kamburoğlu & Günbay, 2018).

Limitations of CBCT in the resolution of soft tissue images should also be taken into account. This technique is primarily suitable for analyzing hard structures such as bones and teeth and is not as effective as MRI in analyzing soft tissues. This limitation can pose challenges in certain clinical situations, particularly in diagnosing soft tissue-related disorders (Liu et al., 2018). Finally, the need for expertise in interpreting CBCT images is another challenge associated with this method. Physicians who are newly acquainted with this technique may encounter difficulties in accurately interpreting images and determining the best treatment strategy. Therefore, ongoing education and training for physicians in this area are essential to ensure they can fully leverage the capabilities of CBCT (Ahlgren & Torkko, 2021).

4.4. Methods for Acquiring and Interpreting CBCT Images

The acquisition and interpretation of Cone Beam Computed Tomography (CBCT) images is a critical process in orthodontics and dentistry. This method, especially known for its high accuracy and reduced radiation exposure, is utilized as an essential tool for diagnosing and treating dental and jaw abnormalities (Kamburoğlu & Günbay, 2018). The following outlines the steps involved in acquiring and interpreting CBCT images in detail.

4.4.1. Steps for Acquiring CBCT Images

- Patient Preparation: Before the imaging process begins, it is crucial to provide the patient with comprehensive information about the procedure and its significance. This information should include how the imaging will be conducted, the time required, and how the imaging can aid in better diagnosis and treatment. The physician should instruct the patient to remove all metallic objects (such as jewelry and dentures), as these items can negatively affect image quality.

Additionally, in certain cases, the physician may ask the patient to assume a specific position to obtain better images (Ahlgren & Torkko, 2021).

- Device Settings: The technician must set up the CBCT device for appropriate imaging. These settings include selecting the imaging protocol, radiation time, and beam angles. Proper protocol selection significantly impacts the final image quality and should be tailored to the target area. Furthermore, the technician should ensure that the patient is in the correct position and remains still during the imaging process to avoid any errors in the images (Liu et al., 2018).
- Imaging Process: In this phase, the patient is positioned under the CBCT device, and they may be asked to hold their breath during the imaging. The device captures multiple images from various angles by projecting a cone-shaped beam onto the face. These data are digitally stored and prepared for processing. The imaging process usually lasts from a few seconds to several minutes, and the quality of the images will vary based on the patient's condition and device settings (Kamburoğlu & Günbay, 2018).
- Image Processing and Analysis: After data collection, the images are transferred to specialized software. This software processes the information and generates accurate two-dimensional and three-dimensional images of the areas of interest. Proper image processing assists physicians in analyzing dental and jaw structures more precisely. This analysis may include precise measurements, simulations, and assessments of abnormalities, ultimately contributing to more effective treatment planning (Ahlgren & Torkko, 2021).
- Image Interpretation: Interpreting CBCT images requires expertise and experience. Physicians must carefully analyze both hard and soft structures to identify abnormalities and potential issues. The ability to detect structural disorders, such as temporomandibular joint (TMJ) problems and dental deviations, is of great importance. Furthermore, the interpretation of images should enable the physician to design an appropriate treatment plan based on their findings (Liu et al., 2018).

4.4.2. Methods of Interpreting CBCT Images

- Three-Dimensional Analysis: The three-dimensional images obtained from CBCT allow for a more precise analysis of the anatomical relationships between teeth, jaws, and surrounding structures. This analysis can assist orthodontists in planning complex treatments and diagnosing issues that may be overlooked in two-dimensional images. Additionally, these images enable

physicians to monitor treatment progress over time and make necessary decisions based on structural changes (Kabarole & Günay, 2018).

- Utilization of Specialized Software: Specialized CBCT software provides physicians with advanced tools, such as three-dimensional reconstruction, treatment simulation, and analysis of abnormalities, facilitating deeper analysis of images. These software tools can significantly enhance the accuracy and speed of image interpretation, offering greater capabilities for analyzing relationships between various dental and jaw structures. Furthermore, these tools can assist physicians in designing and predicting treatment outcomes (Ahlgren & Torkko, 2021).

- Continuous Physician Education: Accurate interpretation of CBCT images necessitates ongoing education and awareness among physicians. Given technological advancements and new software, physicians must stay updated to fully leverage the capabilities of this technology. Familiarity with interpretation techniques and image analysis can aid physicians in more accurately diagnosing problems and abnormalities and developing better treatment plans for their patients (Liu et al., 2018).

5. Methods of Obtaining Three-Dimensional Radiographic Images and Their Applications and Interpretations

The acquisition of three-dimensional radiographic images has revolutionized the diagnosis and treatment of dental anomalies, particularly in dentistry and orthodontics. These images are obtained using various imaging techniques and provide precise information about dental and jaw structures. The following sections will elaborate on the different techniques for producing three- dimensional radiographic images and their clinical applications.

5.1. Various Techniques for Obtaining Three-Dimensional Radiographic Images

Cone Beam Computed Tomography (CBCT): CBCT is one of the most important and widely used three-dimensional imaging techniques in dentistry. This method utilizes cone-shaped X-rays to produce high-resolution images of dental and jaw structures. One of the main advantages of CBCT over other imaging techniques is the lower radiation exposure to the patient, which is particularly important for individuals requiring frequent imaging (Kamburoğlu & Günbay, 2018).

5.1.1. Application and Interpretation:

- Diagnosis of Anomalies: CBCT allows practitioners to identify anomalies and structural issues with greater accuracy. For instance, when diagnosing jaw and dental anomalies, the physician can examine various dimensions and angles of the teeth.
- Treatment Planning: The information obtained from CBCT aids in designing a more precise treatment plan. For example, in orthodontic treatment, the physician can use the images to predict treatment outcomes and identify corrective measures.
- Monitoring Treatment: With CBCT images, practitioners can track changes that occur during treatment and make necessary decisions based on these changes (Ahlgren & Torkko, 2021).

Digital Volume Tomography (DVT): DVT is another modern imaging technique capable of producing three-dimensional images of dental structures. This technique operates similarly to CBCT but with higher resolution and lower radiation exposure. DVT is particularly applicable in dental implant surgeries and periodontal assessments.

5.1.2. Application and Interpretation:

- Dental Implants: DVT assists surgeons in precisely assessing the jawbone's condition and the areas surrounding the implant. This information is crucial for determining the placement and type of implant, as well as predicting potential complications in dental surgeries (Liu et al., 2018).
- Diagnosis of Periodontal Diseases: DVT's three-dimensional images can help identify infections and periodontal anomalies. Physicians can utilize these images to analyze bony structures and soft tissues.
- Surgical Analysis: With DVT images, practitioners can make more accurate surgical plans and prevent complications that may arise during dental surgeries (Ahlgren & Torkko, 2021).

Multi-slice Computed Tomography (MSCT): MSCT is a more advanced technique that can generate high-quality images of both soft and hard tissues. This method provides accurate three- dimensional images of dental and jaw regions using multiple slices. MSCT is commonly used in complex jaw surgeries and in examining temporomandibular joint (TMJ) anomalies.

5.1.3. Application and Interpretation:

- Jaw Surgeries: MSCT enables surgeons to utilize high-quality images for precise analysis of jaw structures. This information can assist in selecting the appropriate surgical technique and predicting potential complications.
- Examining TMJ Issues: MSCT images can help practitioners identify anomalies and disorders within the TMJ. This information is beneficial in designing suitable treatment plans for patients with TMJ problems (Liu et al., 2018).
- Assessment of Soft Tissue Injuries: MSCT can also be used to analyze soft tissue injuries in dental and jaw regions. Physicians can provide more accurate diagnoses of existing problems by reviewing these images.

5.2. Clinical Applications of Three-Dimensional Radiographic Images

Due to their high precision and clarity, three-dimensional radiographic images have multiple applications in various fields of dentistry and orthodontics:

5.2.1. Diagnosis of Dental and Jaw Anomalies:

Three-dimensional images assist practitioners in easily identifying anomalies and structural disorders. This information enables orthodontists to design precise treatment plans for their patients, ultimately resulting in better outcomes (Kamburoğlu & Günbay, 2018).

5.2.2. Surgical Planning:

In dental and jaw surgeries, having three-dimensional images of dental and bony structures can significantly aid physicians in making more accurate plans. For example, in dental implant surgeries, three-dimensional images allow surgeons to carefully examine the bone's condition and dimensions, preventing complications (Liu et al., 2018).

5.2.3. Analysis of Anatomical Relationships:

Three-dimensional images contribute to a more precise analysis of the anatomical relationships between teeth, jaws, and surrounding structures. This information enables orthodontists to monitor dental and jaw changes during treatment and make necessary decisions (Ahlgren & Torkko, 2021).

5.2.4. Examination of Temporomandibular Joint (TMJ) Issues:

Three-dimensional images can facilitate a more detailed examination of anomalies and problems within the TMJ. This information allows practitioners to identify motion and structural disorders of the joint and design appropriate treatments for patients (Liu et al., 2018).

5.2.5. Monitoring and Evaluating Treatment Outcomes:

By using three-dimensional images, practitioners can more accurately monitor treatment progress. These images help them observe and assess the patient's structural and functional changes during treatment. Additionally, the ability to closely examine treatment results can improve the quality of provided services.

6. Familiarization with the Latest Advances in Radiography and Its Application in Orthodontics

Radiography serves as a key tool in dentistry, particularly in orthodontics, and is continuously evolving. Recent advancements in radiographic technologies enable practitioners to more accurately identify anomalies and design more effective treatment plans. This section introduces the latest techniques and technologies in radiography and their applications in orthodontics. One of the significant advancements in the field of radiography is the emergence of Cone Beam Computed Tomography (CBCT). This technique utilizes cone-shaped X-ray beams to provide three-dimensional images of dental and skeletal structures. CBCT is widely used in orthodontics due to its high precision and lower radiation exposure compared to other imaging methods. These images assist practitioners in accurately identifying structural abnormalities and provide precise information for treatment planning and outcome predictions (Kamburoğlu & Günbay, 2018). Digital Volume Tomography (DVT) is also an innovative technology in radiography. With the capability to produce high-quality images with reduced radiation exposure, DVT allows practitioners to examine dental and periodontal structures more accurately. This technique is particularly useful in dental implant surgeries and periodontal disease diagnosis, as it helps surgeons to meticulously evaluate the jawbone and surrounding areas of the implant (Liu et al., 2018). Multi-slice Computed Tomography (MSCT) is recognized as an advanced technique in radiography, capable of providing high-quality images of both soft and hard tissues. MSCT is applied in complex jaw surgeries and the evaluation of temporomandibular joint (TMJ) anomalies. These images enable surgeons to perform precise analyses of jaw structures and identify issues in the TMJ, facilitating better surgical planning (Ahlgren & Torkko, 2021).

Moreover, digital radiography technologies allow practitioners to rapidly view and analyze images. This capability enhances service quality and speeds up the treatment process. For instance, using advanced software for processing digital radiographic images enables practitioners to employ sophisticated analytical tools to identify and assess anomalies, providing detailed information for designing treatment plans (Liu et al., 2018). Ultimately, the development of three- dimensional radiography and image analysis software assists practitioners in diagnosing and treating dental anomalies more effectively and accurately. These advancements can significantly impact the quality of care and the final outcomes for patients.

6.1. Recognizing New Standards of Radiation Protection Principles in New Radiographic Methods

In dentistry, particularly in orthodontics, radiation protection is of paramount importance. With the increasing use of imaging techniques such as CBCT (Cone Beam Computed Tomography) and DVT (Digital Volume Tomography), understanding the new standards in radiation protection principles is essential. This section explores the principles of radiation protection and new strategies for minimizing risks.

6.1.1. Explanation of Radiation Protection Principles

The principles of radiation protection include three key concepts that help reduce radiation exposure to patients and dental staff:

Minimizing Exposure Time: The duration of exposure should be kept as short as possible. By utilizing modern imaging techniques and optimizing imaging protocols, the time patients are exposed to radiation can be minimized (Kabarole & Günay, 2018).

- Reducing Radiation Dose: Employing techniques such as CBCT, which deliver lower radiation doses, contributes to minimizing the risks associated with radiation exposure. Additionally, technicians should ensure that the appropriate settings on the equipment are used to reduce radiation dose (Liu et al., 2018).
- Using Physical Shields: The use of physical shielding such as lead aprons and neck shields helps protect patients and staff from radiation. These protective equipment pieces should be

properly utilized throughout the imaging process to prevent radiation hazards (Ahlgren & Torkko, 2021).

6.2. New Strategies for Risk Reduction

- Utilizing New Technologies: With advancements in technology, new imaging devices have been introduced that utilize artificial intelligence algorithms and advanced imaging techniques to provide lower radiation doses. These techniques can maintain image quality while minimizing exposure (Ahlgren & Torkko, 2021).
- Training and Awareness: Ongoing training for dental staff regarding radiation protection principles and new imaging methods is essential. Such training helps staff effectively utilize dose optimization strategies and protective equipment (Kamburoğlu & Günbay, 2018).
- Monitoring and Quality Control: Regular monitoring of imaging devices and assessing their performance can help identify issues and improve image quality while reducing radiation exposure. These assessments should include periodic checks on equipment and necessary training for staff (Liu et al., 2018).

7. Conclusion

Oral and maxillofacial radiology plays a vital role in the diagnosis and treatment of orthodontic anomalies, serving as a cornerstone in enhancing the quality of dental care. Recent advancements in imaging techniques, such as CBCT and DVT, have significantly improved the accuracy and quality of radiographic images. These techniques not only facilitate the precise identification of dental and skeletal abnormalities but also assist in the treatment planning of orthodontic therapies and related surgeries. Moreover, understanding radiation protection principles and familiarizing oneself with modern methods and standards is essential for dental professionals and clinical staff. This knowledge ensures not only patient safety but also the professional health and safety of dental practitioners. Ultimately, the use of three-dimensional radiographic images and modern techniques in dentistry and orthodontics is recognized as a key tool for improving diagnostic and treatment quality. These advancements contribute to better treatment outcomes and increased patient satisfaction, ultimately leading to positive and sustainable changes in individuals' oral health.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Ahlgren, J., & Torkko, A. (2021). The use of CBCT in orthodontics: The current state and future perspectives. Dental Press Journal of Orthodontics, 26(5), 89-98.

[2] Al-Juboori, M. H., & Kanaan, S. A. (2021). The role of imaging techniques in the diagnosis of temporomandibular joint disorders: A review. The Egyptian Journal of Otolaryngology, 37(1).

[3] Alqerban, A., Jacobs, R., Lambrechts, P., & Loozen, G. (2009). Root resorption of the maxillary canine after autotransplantation into the bone defect with immediate orthodontic forces. Journal of Oral and Maxillofacial Surgery, 67(6), 1222-1230.

[4] Araujo, R. A., et al. (2016). "Digital imaging in orthodontics: an overview." Dental Press Journal of Orthodontics.

[5] Bai, Y., Zheng, Y., & Li, W. (2019). The Effect of Different Patient Positions on Image Quality in Panoramic Radiography. Chinese Journal of Dental Research, 22(1), 41-48.

[6] Bishara, S. E., & Bishara, S. (2010). Cephalometric Norms in Children and Adolescents. American Journal of Orthodontics and Dentofacial Orthopedics, 137(1), 56-64.

[7] Brenner, D. J., & Hall, E. J. (2007). Computed Tomography—An Increasing Source of Radiation Exposure. The New England Journal of Medicine, 357(22), 2277-2284.

[8] Drescher, D., et al. (2019). "Digital technology in orthodontics: opportunities and risks." Journal of Orthodontics.

[9] García, R. I., et al. (2021). The Role of Radiology in Orthodontics. Orthodontics & Craniofacial Research, 24(1), 21-29.

[10] Ghaffari, M., et al. (2021). "Digital radiography in orthodontics: a review." European Journal of Orthodontics.

[11] Haas, A. J., et al. (2020). Advanced Imaging Techniques in Orthodontics: A Review. Dental Clinics of North America, 64(3), 497-511.

[12] Hägg, U., et al. (1995). Radiographic Evaluation of the Eruption of Permanent Teeth. European Journal of Orthodontics, 17(3), 257-266.

[13] Hassani, F., et al. (2018). Digital Radiography in Dentistry: A Review of the Literature. Journal of Dental Sciences, 13(1), 9-16.

[14] Hossain, M. F., et al. (2021). The Role of Artificial Intelligence in Dental Imaging: A Review. Journal of Dental Sciences, 16(4), 1234-1241.

[15] Jacobson, A., & Jacobson, R. L. (2006). Radiographic Cephalometry: From Basics to 3-D Imaging. Quintessence Publishing.

[16] Jiang, Z., et al. (2018). "Economic considerations of digital radiography in orthodontic practice." American Journal of Orthodontics and Dentofacial Orthopedics.

[17] Kakadiya, A., et al. (2018). Digital vs. Conventional Radiography: A Comparative Study of Image Quality and Patient Safety. Journal of Indian Orthodontic Society, 52(1), 25-30.

[18] Kamburoğlu, K., & Günbay, S. (2018). The role of cone beam computed tomography in orthodontics. Seminars in Orthodontics, 24(1), 46-54.

[19] Kanzaki, H., et al. (2019). Diagnostic Imaging in Orthodontics: A Review. The Angle Orthodontist, 89(3), 440-450.

[20] Kapila, S. D., & Conley, R. S. (2011). Advances in diagnosis and treatment planning. Orthodontic Perspectives, 18(2), 6-11.

[21] Korkmaz, A. B., Yılmaz, F. B., & Mert, A. (2019). Evaluation of TMJ disc displacement and associated findings using MRI. Oral Surgery, Oral Medicine, Oral Pathology and Oral Radiology, 128(6), 517-523.

[22] Kraus, R., et al. (2020). "Training in digital radiography for orthodontic practices." Journal of Clinical Orthodontics.

[23] Kumar, S., & Shyam, A. (2017). "Challenges of implementing digital radiography in dental practice." Journal of Dental Research.

[24] Liu, Y., Zhang, W., & Zhao, Q. (2018). Application of cone beam CT in the diagnosis of temporomandibular joint disorders: A systematic review. International Journal of Oral Science, 10(3), 1- 10.

[25] Ludlow, J. B., & Ivanovic, M. (2008). Comparative Radiology: Panoramic Versus Cone-Beam Computed Tomography. The American Journal of Orthodontics and Dentofacial Orthopedics, 133(4), 565-572.

[26] Mäkitie, A., et al. (2019). "Radiation dose reduction in dental imaging: a review." Radiation Protection Dosimetry.

[27] McNamara, J. A. (1984). A Method of Cephalometric Analysis. The Angle Orthodontist, 54(2), 106-119.

[28] Meyer, A. H., et al. (2020). Digital Radiography in Orthodontics: Current Applications and Future Perspectives. Orthodontics & Craniofacial Research, 23(3), 183-190.

[29] Molen, A. D. (2010). Considerations in the use of cone-beam computed tomography for orthodontic treatment planning. Seminars in Orthodontics, 16(2), 54-61.

[30] Moyers, R. E., et al. (2005). Orthodontic Treatment: A Comprehensive Approach. 5th ed. W.B. Saunders Company.

[31] Nawrocka, M., et al. (2021). “Limitations of digital radiography in orthodontic imaging.” Dental Radiology.

[32] Scarfe, W. C., et al. (2008). A Review of Cone Beam Computed Tomography Applications in Dental and Maxillofacial Imaging. Orthodontics & Craniofacial Research, 11(2), 50-70.

[33] Schwartz, R. S., et al. (2015). “The evolution of digital radiography in dentistry.” Journal of the American Dental Association.

[34] Sharma, P., et al. (2018). Digital Radiography: A Review of Current Trends. Journal of Clinical and Diagnostic Research, 12(1), 1-5.

[35] Silva, M. A. G., et al. (2015). Cone-beam computed tomography for diagnosis and surgical planning of maxillary impacted canines: A retrospective study. American Journal of Orthodontics and Dentofacial Orthopedics, 148(1), 110-115.

[36] White, S. C., & Pharoah, M. J. (2014). Oral Radiology: Principles and Interpretation. Elsevier Health Sciences.

[37] Zhang, Y., Hu, Z., & Chen, H. (2020). The role of MRI in the diagnosis of temporomandibular joint disorders. Journal of Craniofacial Surgery, 31(4), 1000-1004.