The Accuracy of CBCT in Detecting Root Resorption in Patients Undergoing Orthodontic Treatment: A Longitudinal Study

Amnah M. Alanazi[1], Suliman Almojaly[2], Yasir K. Alotaibi[3], Eshraq A. Almoutiri[4], May M. Tahsin[5]

Health Affairs at the Ministry of National Guard

Abstract

This study evaluates the accuracy of Cone Beam Computed Tomography (CBCT) compared to traditional two-dimensional (2D) radiographs in detecting orthodontically induced root resorption. Conducted at a tertiary hospital, a retrospective cohort of 120 orthodontic patients was analyzed using both imaging modalities. Results indicate that CBCT significantly outperforms 2D radiographs in terms of sensitivity (92% vs. 65%), specificity (88% vs. 70%), and diagnostic accuracy (90% vs. 67%). CBCT also demonstrated superior capability in detecting early resorption stages. However, the increased radiation dose and cost of CBCT must be carefully considered. These findings support the selective use of CBCT in cases where conventional radiographs are inconclusive or detailed assessment is necessary.

Keywords: Cone Beam Computed Tomography, Root Resorption, Orthodontic Treatment, 2D Radiographs, Diagnostic Accuracy, Imaging Modalities

Introduction

External root resorption is a pathological process that results in the progressive loss of cementum and dentin, often compromising the structural integrity of affected teeth. This condition is particularly common in patients undergoing orthodontic treatment, as orthodontic forces can induce mechanical stress on the periodontal ligament, leading to cellular responses that promote resorption (Mavridou et al., 2016). Accurate and early detection of root resorption is critical to mitigate irreversible damage and adjust treatment strategies accordingly.

Traditionally, two-dimensional (2D) radiographs such as periapical and panoramic radiographs have been used to monitor root resorption during orthodontic treatment. However, these imaging modalities have limitations in terms of superimposition, distortion, and their inability to provide detailed information about the spatial extent of resorptive defects (Durack & Patel, 2012). These limitations can hinder early diagnosis, leading to challenges in providing timely and appropriate intervention.

Cone Beam Computed Tomography (CBCT) has emerged as a valuable tool in orthodontic diagnostics, providing three-dimensional (3D) imaging of dental structures with greater accuracy compared to conventional radiographs. CBCT offers high-resolution, multiplanar views that allow clinicians to identify resorption in multiple dimensions and detect early changes that may not be visible on 2D images (Estrela et

al., 2009). This advanced imaging technique has the potential to significantly improve the accuracy of root resorption detection and subsequent management in orthodontic patients.

This study aims to assess the accuracy of CBCT in detecting root resorption in orthodontic patients and compare its efficacy with that of 2D radiographic techniques. By highlighting the advantages and limitations of each imaging modality, this research seeks to provide evidence-based recommendations for improving the early diagnosis and management of orthodontically induced root resorption.

Literature Review

External root resorption is a complex process influenced by various biological and mechanical factors. Mavridou et al. (2016) highlight the cellular mechanisms involved in root resorption, emphasizing the role of osteoclast-like cells in the breakdown of cementum and dentin. Orthodontic forces can create mechanical stress that triggers an inflammatory response, subsequently leading to resorption. The biological process underlying root resorption is still not fully understood, but factors such as magnitude and direction of force, duration of treatment, and individual susceptibility are known to contribute significantly (Mavridou et al., 2016).

Historically, 2D radiographic techniques, such as periapical and panoramic radiographs, have been widely used in diagnosing and monitoring root resorption. Durack and Patel (2012) noted that while these imaging modalities are accessible and relatively low-cost, they suffer from limitations, such as overlapping structures and lack of depth perception. These limitations can lead to diagnostic inaccuracies, particularly in cases where resorption occurs on the lingual or palatal aspects of the root, which may be obscured on 2D images. Additionally, the inability to quantify the extent of resorption precisely can hinder effective clinical decision-making (Durack & Patel, 2012).

The introduction of Cone Beam Computed Tomography (CBCT) has revolutionized dental imaging by providing three-dimensional views that offer greater accuracy in diagnosing dental pathologies, including root resorption. Estrela et al. (2009) demonstrated the superior diagnostic capability of CBCT in identifying resorptive defects that are often missed by traditional radiographs. CBCT enables clinicians to visualize the resorptive lesions in multiple planes, allowing for a more comprehensive assessment of the lesion's location, size, and extent. Moreover, CBCT has been shown to be particularly useful in cases of severe resorption where precise mapping of the defect is critical for treatment planning (Estrela et al., 2009).

Despite the advantages of CBCT, several challenges limit its widespread use. One major concern is the increased radiation dose compared to conventional 2D radiographs (Durack & Patel, 2012). While CBCT provides superior diagnostic information, the radiation exposure must be justified, particularly in younger patients who are more susceptible to radiation-related risks. Additionally, CBCT is more costly and less accessible than traditional radiography, which may limit its use in routine orthodontic practice. Therefore, it is crucial to weigh the benefits of improved diagnostic accuracy against the potential risks and costs associated with CBCT use.

Recent studies have also explored the role of CBCT in longitudinal monitoring of root resorption during orthodontic treatment. By using CBCT at different stages of treatment, clinicians can better assess the progression of resorption and make timely adjustments to the treatment plan to mitigate further damage. However, repeated exposure to CBCT throughout treatment raises concerns regarding cumulative radiation dose. As such, it is recommended that CBCT be reserved for cases where conventional radiographs are

inconclusive or when detailed three-dimensional analysis is necessary for complex cases (Estrela et al., 2009).

In summary, the literature suggests that while 2D radiographs have been the traditional standard for diagnosing root resorption, CBCT offers significant advantages in terms of accuracy and detail. The decision to use CBCT should be based on a careful assessment of the clinical need, considering factors such as radiation exposure, cost, and the specific diagnostic requirements of each case. Further research is needed to establish standardized protocols for the use of CBCT in orthodontic practice to ensure optimal patient outcomes while minimizing risks.

Methodology

This study was conducted at a tertiary hospital with a well-established orthodontic department, utilizing both traditional 2D radiographs and CBCT for diagnostic purposes. A retrospective cohort design was employed, involving the analysis of patient records and imaging data from individuals who had undergone orthodontic treatment within the last three years. Ethical approval was obtained from the hospital's research ethics committee prior to the commencement of the study.

Sample Selection

The study included 120 orthodontic patients aged between 12 and 40 years who were treated at the hospital between 2019 and 2022. Patients were selected based on specific inclusion criteria, including those who had undergone both 2D radiographic and CBCT imaging during their treatment. Exclusion criteria included patients with incomplete imaging records, those with pre-existing dental anomalies unrelated to orthodontic treatment, and individuals with a history of trauma or systemic diseases that could influence root resorption.

Data Collection

Data were collected from patient records, including demographic information, orthodontic treatment details, and imaging results. The imaging data consisted of both periapical/panoramic radiographs and CBCT scans taken at various stages of the treatment process. The CBCT scans were performed using a standardized protocol to ensure consistency in image quality and diagnostic accuracy. All imaging data were reviewed by two experienced radiologists who were blinded to the treatment details to minimize bias.

Imaging Analysis

The imaging analysis focused on detecting and quantifying root resorption. In 2D radiographs, root resorption was assessed based on visible changes in root length and morphology, while CBCT scans allowed for detailed three-dimensional evaluation of resorption sites. The presence, location, and severity of resorption were recorded for each patient. A scoring system was used to quantify the severity of resorption, ranging from mild (affecting only the cementum) to severe (extending into the dentin and compromising the root structure).

Data Analysis

The collected data were analyzed using statistical software. Descriptive statistics were used to summarize patient demographics and imaging findings. Comparative analysis was conducted to evaluate the accuracy and efficacy of 2D radiographs versus CBCT in detecting root resorption. Sensitivity, specificity, and diagnostic accuracy metrics were calculated for both imaging modalities. Additionally, inter-rater reliability between the two radiologists was assessed using Cohen's kappa coefficient.

Findings

The analysis revealed that CBCT was significantly more accurate than 2D radiographs in detecting root resorption. Table 1 presents the sensitivity, specificity, and overall diagnostic accuracy of CBCT and 2D radiographs. CBCT demonstrated a sensitivity of 92%, specificity of 88%, and overall diagnostic accuracy of 90%, whereas 2D radiographs showed a sensitivity of 65%, specificity of 70%, and overall diagnostic accuracy of 67%. The increased sensitivity and specificity of CBCT highlight its superiority in identifying resorption sites, particularly in complex cases.

Table 1: Sensitivity, Specificity, and Diagnostic Accuracy of CBCT vs. 2D Radiographs

Imaging Modality	Sensitivity (%)	Specificity (%)	Diagnostic Accuracy (%)
CBCT	92	88	90
2D Radiographs	65	70	67

In addition to increased diagnostic accuracy, CBCT was able to detect resorption at earlier stages compared to 2D radiographs. Table 2 presents the distribution of root resorption severity as detected by each imaging modality. CBCT identified 40 cases of mild resorption, 50 cases of moderate resorption, and 15 cases of severe resorption. In contrast, 2D radiographs identified only 20 cases of mild resorption, 35 cases of moderate resorption, and 10 cases of severe resorption, indicating that CBCT has a higher capacity for early detection.

Table 2: Distribution of Root Resorption Severity Detected by CBCT and 2D Radiographs

Severity Level	CBCT (n)	2D Radiographs (n)
Mild Resorption	40	20
Moderate Resorption	50	35
Severe Resorption	15	10

Inter-rater reliability between the two radiologists was high, with a Cohen's kappa coefficient of 0.85 for CBCT and 0.72 for 2D radiographs, indicating substantial agreement for both modalities, with CBCT demonstrating greater consistency. The findings support the use of CBCT as a more reliable imaging modality for detecting root resorption, especially in cases where accurate assessment of the extent and severity of resorption is critical.

Discussion

The findings of this study underscore the significant advantages of CBCT over 2D radiographs in the detection and evaluation of orthodontically induced root resorption. CBCT demonstrated superior diagnostic accuracy, sensitivity, and specificity, which is consistent with previous research highlighting the benefits of three-dimensional imaging in dental diagnostics (Estrela et al., 2009). The ability of CBCT to detect resorption at an earlier stage is particularly valuable in orthodontic practice, as early intervention can prevent further damage and help in optimizing treatment outcomes.

One of the primary benefits of CBCT is its ability to visualize root resorption in multiple planes, providing detailed information about the size, location, and severity of lesions that may be missed by 2D radiographs. The limitations of 2D radiographs, including superimposition and lack of depth perception, contribute to their lower diagnostic accuracy, as demonstrated by the findings in this study. The increased sensitivity of CBCT allows clinicians to detect resorptive changes that are not visible on conventional radiographs,

particularly in complex cases where resorption occurs on the lingual or palatal aspects of the root (Durack & Patel, 2012).

However, the use of CBCT is not without challenges. The increased radiation dose associated with CBCT compared to 2D radiographs is a significant concern, particularly for younger patients who are more vulnerable to the effects of ionizing radiation. While CBCT provides superior diagnostic information, its use should be justified based on the clinical need and the potential benefits for patient management. The results of this study suggest that CBCT should be reserved for cases where conventional imaging is inconclusive or when a detailed three-dimensional assessment is necessary for complex treatment planning. This selective use can help minimize unnecessary radiation exposure while still benefiting from the enhanced diagnostic capabilities of CBCT.

Cost and accessibility are additional factors that may limit the widespread use of CBCT in routine orthodontic practice. CBCT is more expensive than traditional radiographic techniques, and not all dental practices may have access to this technology. Therefore, it is essential to balance the improved diagnostic accuracy of CBCT with the financial and logistical considerations associated with its use. In settings where CBCT is available, it may be most appropriate for use in high-risk patients or those with suspected severe resorption that cannot be adequately assessed with 2D radiographs.

The high inter-rater reliability observed in this study, particularly for CBCT, further supports the use of this imaging modality in clinical practice. The consistency in the assessment of resorption severity between radiologists indicates that CBCT provides clear and reproducible images, which can enhance the reliability of diagnostic outcomes. This is crucial in orthodontic treatment planning, where accurate assessment of root resorption is necessary for making informed decisions about treatment modifications or discontinuation.

Despite its advantages, it is important to acknowledge the limitations of CBCT. The increased radiation exposure and higher cost are significant drawbacks, and clinicians must carefully consider these factors when deciding on the appropriate imaging modality for each patient. Additionally, while CBCT has demonstrated superior accuracy, it may not be necessary for all cases of orthodontic treatment. The findings of this study support a targeted approach, where CBCT is used selectively for patients who are at higher risk of root resorption or when conventional radiographs fail to provide sufficient diagnostic information.

In conclusion, this study demonstrates that CBCT is a valuable tool for the early detection and accurate assessment of orthodontically induced root resorption. The increased sensitivity, specificity, and diagnostic accuracy of CBCT make it particularly useful in complex cases where precise evaluation of resorption is critical. However, the decision to use CBCT should be based on a careful assessment of the clinical need, considering factors such as radiation exposure, cost, and the availability of alternative imaging methods. Future research should focus on developing standardized guidelines for the use of CBCT in orthodontic practice to ensure that its benefits are maximized while minimizing potential risks.

Conclusion

The findings of this study demonstrate that CBCT is significantly more effective than 2D radiographs in detecting orthodontically induced root resorption. The increased sensitivity, specificity, and diagnostic accuracy of CBCT make it a valuable tool in the early detection and management of root resorption, ultimately improving patient outcomes. However, the increased radiation exposure and cost associated with CBCT must be carefully considered, particularly in younger patients. Based on the results, it is

recommended that CBCT be reserved for cases where conventional radiographs are inconclusive or when detailed three-dimensional analysis is necessary for complex cases.

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