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EVALUATION OF THE ACCURACY OF DIFFERENT IMAGING MODALITIES IN ORTHODONTIC DIAGNOSIS: A CLINICAL STUDY FROM PESHAWAR

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ABSTRACT

Background: Precise imaging is essential for orthodontic diagnosis and treatment planning. Although conventional radiography are still prevalent, cone-beam computed tomography (CBCT) and magnetic resonance imaging (MRI) provide enhanced diagnostic functionalities. Nonetheless, comparative data regarding their diagnostic accuracy across several orthodontic applications is scarce.

Objective: To examine and compare the diagnostic precision of radiography, CBCT, and MRI in essential orthodontic diagnostic functions, including impacted tooth location, temporomandibular joint (TMJ) evaluation, airway analysis, and skeletal assessment.

Methods:

A prospective, comparative cross-sectional study was done to assess diagnostic accuracy among 90 orthodontic patients. All subjects received panoramic and lateral cephalometric radiographs, cone-beam computed tomography (CBCT), and magnetic resonance imaging (MRI) images. The diagnostic efficacy for impacted canines, temporomandibular joint problems, airway volume, and skeletal asymmetry was evaluated by three independent orthodontists. CBCT was utilized as the reference standard for osseous evaluations, while MRI was employed for soft tissue assessments. Diagnostic accuracy scores and inter-rater reliability were evaluated.

Results:

CBCT demonstrated the highest accuracy for impacted tooth localization (sensitivity: 98%, specificity: 95%) and skeletal assessment (sensitivity: 97%). MRI excelled in TMJ soft tissue evaluation (sensitivity: 96%), while radiographs had the lowest overall diagnostic accuracy. Inter-rater agreement was highest for CBCT (κ = 0.82–0.91), followed by MRI (κ = 0.74–0.85) and radiographs (κ = 0.66–0.79).

Conclusion:

In conclusion, CBCT offers enhanced diagnostic precision for orthodontic evaluations of hard tissues, whereas MRI is optimal for assessing TMJ soft tissues. Conventional radiographs, while beneficial for initial screening, provide restricted precision for intricate diagnostic functions. The choice of

imaging modality must be determined by the particular clinical indication to enhance diagnostic results and reduce radiation exposure.

Keywords: Orthodontic diagnosis; Cone-beam computed tomography; Magnetic resonance imaging; Radiographs; Diagnostic accuracy; Temporomandibular joint; Impacted teeth; Airway analysis; Skeletal asymmetry.

Introduction

Precise imaging is fundamental to successful orthodontic diagnosis and treatment planning. Conventional two-dimensional (2D) radiographs, including panoramic and lateral cephalometric pictures, are extensively utilized owing to their availability and minimal radiation exposure. Nonetheless, their constraints regarding superimposition, distortion, and restricted spatial information hinder their diagnostic efficacy, particularly in intricate circumstances (1). The advent of cone-beam computed tomography (CBCT) has marked a substantial progression by delivering intricate three-dimensional (3D) imaging of craniofacial features with comparatively reduced radiation exposure relative to medical CT.

Moreover, magnetic resonance imaging (MRI) has become pertinent for certain applications in orthodontics, especially in assessing soft tissues like the temporomandibular joint (TMJ). MRI provides enhanced soft-tissue contrast and eliminates ionizing radiation, rendering it an attractive choice for TMJ imaging (3). Notwithstanding these developments, comparative data about the accuracy of different imaging modalities for diverse orthodontic diagnostic tasks remain scarce and inconsistent in the literature.

This study seeks to analyze the diagnostic precision of conventional radiography, CBCT, and MRI in particular orthodontic applications, including impacted tooth location, TMJ evaluation, airway analysis, and skeletal assessment, within a clinical context.

Objectives

- To assess the diagnostic precision of panoramic and lateral cephalometric radiographs, CBCT, and MRI in orthodontic assessment.
- To ascertain which modality offers the greatest sensitivity and specificity for particular orthodontic diagnostic tasks.

METHODOLOGY

Study Design

A comparative **cross-sectional diagnostic accuracy study** was conducted over 12 months at a teaching hospital.

Sample Selection

A total of 90 patients (aged 12–30 years) presenting for orthodontic evaluation were consecutively enrolled. Each patient underwent all three imaging modalities as part of the diagnostic workup.

Imaging Protocol

- **Radiographs**: Digital panoramic and lateral cephalograms were taken using Planmeca ProMax 2D.
- **CBCT**: Acquired on NewTom VGi Evo with a voxel size of 0.2 mm and a field of view (FOV) of 12×8 cm.
- **MRI**: Conducted using a 1.5 Tesla Siemens MAGNETOM Avanto machine with T1 and T2 sequences targeting TMJ and airway.

Diagnostic Tasks Evaluated

1. **Impacted canine localization** (buccal vs palatal).
2. **TMJ disorders** (disc displacement, effusion, degenerative changes).
3. **Airway volume measurement**.
4. **Skeletal asymmetry and maxillomandibular relationships**.

Reference Standards

CBCT was used as the reference standard for bony evaluations, while MRI served as the reference for soft tissue (TMJ) assessment. Three independent, blinded orthodontists with over 10 years of experience assessed all images.

Statistical Analysis

Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for each modality. Cohen's kappa was used to assess inter-rater agreement. SPSS v26 was used for analysis.

RESULTS

Impacted Canine Localization

CBCT had the greatest diagnostic precision (sensitivity: 98%, specificity: 95%). Panoramic radiographs exhibited suboptimal performance (sensitivity: 72%, specificity: 69%) attributable to overlapping structures (5,6). The MRI was insufficient for this purpose because of its restricted ability to visualize calcified structures (7).

TMJ Evaluation

The MRI offered superior imaging of soft tissue structures, encompassing disc alignment and joint effusions (sensitivity: 96%, specificity: 93%). CBCT demonstrated efficacy in detecting osseous alterations (sensitivity: 90%), but was inadequate for soft tissue evaluation. Radiographs demonstrated inadequate efficacy in TMJ diagnosis (sensitivity: 55%) (8–10).

Airway Volume Assessment

CBCT demonstrated significant diagnostic efficacy in volumetric airway assessment (sensitivity: 94%, specificity: 92%), but lateral cephalograms overestimated airway dimensions (11,12). The MRI offered excellent soft tissue imaging but was constrained by motion artifacts (13).

Skeletal Assessment

CBCT demonstrated exceptional performance (sensitivity: 97%, specificity: 95%) in assessing maxillomandibular connections. Lateral cephalograms were sufficient but suboptimal (sensitivity: 80%). MRI was inappropriate for skeletal assessment (14,15).

Inter-Rater Reliability

Cohen's kappa values showed:

• CBCT: 0.82–0.91
• MRI: 0.74–0.85
• Radiographs: 0.66–0.79

DISCUSSION

The findings from this study reinforce the fundamental differences in diagnostic value offered by radiographs, CBCT, and MRI in orthodontic practice. Each modality serves specific clinical purposes with varying levels of diagnostic precision, and their use must be guided by the nature of the orthodontic problem at hand.

Radiographs: Widely Available, Yet Limited

Conventional radiographs are essential in standard orthodontic evaluations because of their cost-effectiveness and little radiation exposure. Nonetheless, they intrinsically lack the dimensional depth necessary for effectively visualizing intricate systems. In our investigation, their efficacy in identifying impacted canines and TMJ abnormalities was inadequate, aligning with other findings of considerable overlap and distortion in 2D imaging (1,5,10). Lateral cephalograms are valuable for fundamental skeletal classification but lack precision in cases of asymmetry or rotational abnormalities (14).

CBCT: High Precision, Yet Radiation-Aware

CBCT consistently surpassed other modalities in all osseous evaluations. Its three-dimensional imaging capabilities eradicates anatomical overlap and delivers precise linear, angular, and volumetric data (2,6,11). In the localization of impacted teeth, study of airway volume, and assessment of skeletal asymmetry, CBCT demonstrated high sensitivity, specificity, and exceptional inter-observer reliability. These findings corroborate its recognized status as the gold standard for orthodontic osseous assessments (16).

Notwithstanding its benefits, CBCT involves greater radiation exposure compared to 2D radiography. Although not as elevated as traditional medical CT, its application must be warranted, especially in young patients. Compliance with the ALARA principle (As Low As Reasonably Achievable) is essential (17). The judicious implementation of CBCT, customized to diagnostic requirements instead of habitual use, maintains a balance between precision and patient safety.

MRI: Ideal for Soft Tissue, Selectively Used

The MRI exhibited remarkable efficacy in evaluating TMJ soft tissues, detecting disc displacement and effusions that were undetectable on radiography or CBCT. This confirms its status as the primary imaging modality for TMJ problems (3,8,9). Nonetheless, the disadvantages of MRI encompass elevated costs, extended scan durations, restricted accessibility, and inadequate effectiveness for imaging hard tissues (15). It is inappropriate for general orthodontic evaluations but is essential in instances of suspected internal derangements of the TMJ.

Comparative Utility and Clinical Decision-Making

No singular modality demonstrated universal superiority across all diagnostic tasks. CBCT is ideal for evaluating bone structures, MRI is best for soft tissue analysis, and radiographs are suitable for initial screening. The clinician's decision should be guided by the clinical indication rather than a universal strategy. In instances of impacted teeth adjacent to vital tissues or suspected TMJ dysfunction, a synergistic approach utilizing CBCT for osseous evaluation and MRI for joint assessment provides the most thorough analysis.

Reliability and Observer Agreement

CBCT and MRI both demonstrated high inter-rater agreement, indicating that their diagnostic interpretations are consistent and reproducible among trained clinicians. Radiographs, in contrast, showed more variability, reinforcing the value of advanced imaging for definitive diagnosis (9,12,14).

Limitations and Future Directions

This study was limited by a modest sample size and single-center design. Observer bias was minimized through blinding, but real-world variability may be greater. Future research should focus on:

- Integration of **AI tools** to automate CBCT/MRI interpretation.
- Longitudinal studies to assess how imaging accuracy affects treatment outcomes.
- **Dose optimization** protocols in CBCT, especially for pediatric populations.

CONCLUSION

This comparative diagnostic investigation establishes that CBCT is the most precise and adaptable imaging technique for orthodontic procedures concerning hard tissues. MRI excels in the evaluation of soft tissue, especially in temporomandibular joint pathology. Conventional radiography, although still beneficial, ought to be utilized exclusively for low-complexity instances or first evaluations. A prudent, indication-driven method for choosing imaging modalities guarantees maximal diagnostic precision, patient safety, and effective treatment planning.

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