Accuracy of Micro Hole Negotiator and Other Techniques for Detecting MB2 Canals in Maxillary Molar Retreatment: A Prospective Cohort Study

ABSTRACT

This clinical study evaluated four diagnostic approaches for locating the orifice of the second mesiobuccal canal (MB2) during root canal retreatment of maxillary molars: direct visual inspection, the Micro Hole Negotiator electronic device, the dental operating microscope, and their combined use. A stepwise protocol was used in 124 retreatment cases, applying each method sequentially. Detection rates of MB2 canals increased progressively, with the combined use of the microscope and electronic device yielding the highest adjusted diagnostic efficiency, followed by the microscope alone, the electronic device alone, and direct visual inspection. These findings suggest that optical magnification and impedance-based electronic feedback can enhance canal identification, particularly under complex retreatment conditions. The electronic device outperformed direct visual inspection and may enhance the detection of MB2 canals in clinical settings where a microscope is unavailable.

Keywords: dental operating microscopes; endodontics; maxilla; root canal therapy; second mesiobuccal canal.

1. Introduction

The root canal anatomy of maxillary molars is often complex, with the mesiobuccal root having challenging morphological variations. Numerous studies have reported that the prevalence of a second mesiobuccal (MB2) canal in maxillary first molars ranges from 36.3% to 97.6%, while in maxillary second molars, it varies between 8.5% and 53.14% [1-4]. As a result, the majority of maxillary molars contain four canals. The clinical detection of MB2 canals is influenced by several factors, including the operator's experience, duration of the procedure, diagnostic methods employed, calcification and obliteration of the pulp chamber and canal orifices, and the tooth's treatment history [5, 6]. The incidence of missed canals in maxillary first molars has been reported to range from 41.3% to 46.5% [7, 8], which implies that detecting MB2 canals is challenging [9, 10].

Root canal retreatment as a consequence of post-treatment endodontic disease in previously root filled teeth often presents with complex clinical scenarios. In contrast, primary root canal treatment maintains the original anatomical configuration, making canal orifice detection and negotiation comparatively straightforward [11]. In retreatment cases, however, identifying and accessing MB2 canals becomes more difficult due to anatomical alterations, debris accumulation, canal obstructions, and iatrogenic complications [11]. Undetected and untreated canals may harbor sufficient bacterial loads to perpetuate existing periapical disease [12]. Root canal retreatments constitute a significant proportion of cases, and their success plays a vital role in preserving the natural dentition and preventing extraction or surgical interventions [13]. As missed MB2 canals are a leading cause of post-treatment disease in maxillary molars [8, 14], their detection and treatment is crucial. Missing the MB2 canal during root canal treatment can lead to persistent intraradicular infection, post-treatment apical periodontitis, and a reduced long-term prognosis for maxillary molars. Failure to locate and treat the MB2 canal may result in incomplete cleaning and filling of the root canal system, increasing the risk of emerging or persistent periapical lesions and the need for retreatment [8, 12]. Therefore, accurate detection and management of MB2 canals are essential to achieve predictable outcomes. Clinicians are therefore advised to use appropriate supplementary diagnostic methods to identify and locate additional canals that may be difficult to detect by simple direct visualization. The use of advanced techniques and technologies can significantly improve the detection rate of MB2 canals [15].

The direct visual method (DVM) has long been used to identify root canal orifices, but when employed alone, its success rate for MB2 detection can be as low as 17% [16]. The dental

operating microscope (DOM) offers enhanced visualization through magnification and illumination, improving the ability to detect canal orifices by revealing intricate anatomical details [17]. The Micro Hole Negotiator (MHN) is an innovative endodontic device developed to assist clinicians in identifying root canal orifices, particularly in teeth with calcified pulp chambers and complex internal anatomy [18]. The MHN is designed to detect subtle variations in electrical conductivity and impedance within the pulp chamber, providing real-time visual and auditory feedback to guide the clinician toward canal orifices. The technology has been integrated into two apex locator systems (Guilin Woodpecker Medical Instrument Co., Ltd., Guilin, China), and marketed as Dpex X MHN and Woodpex X MHN. These devices combine conventional apex locator capabilities with a dedicated orifice-finding (MHN) mode, claimed to allow more precise and controlled exploration of the pulp chamber. This dual functionality is claimed to enhance the detection of hard to detect orifices and overcome limitations associated with conventional methods such as direct vision or magnification alone [18].
Periapical radiographs remain the standard imaging modality in routine endodontic procedures due to their accessibility and low radiation exposure. However, cone-beam computed tomography (CBCT) may be indicated in complex cases or those involving suspected untreated canals, as it provides three-dimensional visualization and improves diagnostic accuracy [2]. CBCT allows comprehensive imaging of internal tooth structures, enabling a better understanding of root canal morphology than conventional two-dimensional radiography [19]. Although several studies have examined MB2 detection during root canal treatment, limited research exists regarding its identification in root canal retreatment using different diagnostic techniques [20]. To date, no clinical study has evaluated the application of the Micro Hole Negotiator (MHN) in this context.

The aim of this study was to assess the diagnostic performance of four different methods—direct visual method (DVM), Micro Hole Negotiator (MHN), dental operating microscope (DOM), and the combined use of DOM and MHN—for detecting the orifices of MB2 canals in cases undergoing root canal retreatment.

2. Material and Methods

Study design

This study was designed as a prospective cohort investigation to evaluate the effectiveness of stepwise diagnostic methods in locating MB2 canal orifices during root canal retreatment. The study protocol adhered to the ethical principles outlined in the Declaration of Helsinki and was approved by the institutional ethics committee.

Participants were recruited from patients referred to the Department of Endodontics at the XXXX University, Faculty of Dentistry. A total of 130 patients who met the inclusion criteria were enrolled in the study.

Patient Selection and Diagnostic Protocol

Patients who had previously received root canal treatment on maxillary first or second molars and required root canal retreatment were eligible for inclusion. Participants ranged in age from 18 to 50 years, regardless of gender, and were systemically healthy. Teeth with open apices, internal or external resorptions, or other exclusionary pathological conditions were not included in the study.

The detection of the second mesiobuccal (MB2) canal was performed using a four-step sequential protocol:

Step 1 – Direct Visual Method (DVM)

Step 2 – Canal finder mode of the Dpex X MHN apex locator

Step 3 – Dental Operating Microscope (DOM)

Step 4 – Combined use of DOM and the Dpex X MHN canal finder mode

All participants underwent step 1 evaluation. If the MB2 canal was not located, the diagnostic process continued sequentially through steps 2, 3, and 4.

Clinical procedures

Initial clinical evaluation included assessment of existing dental restorations. Where necessary, resin composite build-ups were performed to restore coronal structure prior to access cavity preparation. Local infiltration anaesthesia was administered using 4% articaine with 1:100,000 epinephrine (Ultracaine D-S Forte, Aventis, Istanbul, Turkey), and rubber dam isolation was applied.

Access cavities were prepared conventionally using endodontic access burs (Dentsply Maillefer, Ballaigues, Switzerland). The mesiobuccal 1 (MB1), distobuccal, and palatal canals were initially located using a size 15 K-file and an endodontic explorer. Root canal retreatment was initiated with the removal of residual gutta-percha and intracanal materials. The canals were instrumented to the canal terminus with size 10, .06 taper NiTi rotary files (Super System Minimal Invasive, Perfect Medical Instruments Co. Ltd, Shenzen, China), and disinfected using 3% sodium hypochlorite. All procedures were performed by a calibrated operator.

Subsequently, the pulp chamber floor was examined through the following four-step protocol for the detection of the MB2 canal:

Step I: Direct Visual Method (DVM)

Initial exploration of the pulp chamber was conducted under standard dental unit lighting, without magnification. An endodontic explorer (DG16, Hu-Friedy), rhodium mirror, and hand files (sizes 6–10 stainless steel or NiTi K-files) were used to probe for the MB2 canal. The explorer was guided 1–2 mm mesially from the MB1 canal toward the palatal aspect. In cases with calcified dentine, the chamber floor was modified using ultrasonic tips or long-neck burs. Irrigation with 3% sodium hypochlorite was performed intermittently. MB2 orifice detection was confirmed by successful negotiation with a size 10 K-file and radiographic working length verification. If detection was unsuccessful, the procedure advanced to Step II.

Step II: MHN Mode

The MHN mode functions through capacitance- and impedance-based detection. It senses microvariations in electrical impedance across the pulp chamber floor to differentiate between dentine and canal orifices. As the probe approaches a canal orifice, changes in capacitance and impedance generate real-time visual and auditory feedback, helping the operator locate the canal with greater precision [18].

In this step, the MB2 canal was investigated using the MHN mode of the Dpex X MHN apex locator. This mode was activated by pressing the selection button for 3 s.

Before initiating exploration with the MHN, the pulp chamber floor was dried thoroughly to prevent short-circuit signals due to residual moisture using an air spray directed perpendicular to the long axis of the tooth and parallel to the occlusal surface.

The probe of the device was indented by pushing into the suspected areas of the chamber floor to assess whether it generated a signal indicative of a canal orifice. The visual feedback on the device screen followed a numerical scale:

0–1: No electrical connection

2–3: Signal forming

4–9: Orifice detected

10: Possible perforation

Lower values indicated no contact with canals, while higher values signaled close proximity. Ultrasonic tips and long-neck burs were used to remove obstructing dentine if necessary. If the MB2 canal could not be identified at this stage, the procedure progressed to Step III.

Step III: Dental Operating Microscope (DOM)

This step utilized ×16 magnification with a dental operating microscope (Leica M320, Leica Microsystems, Wetzlar, Germany) equipped with integrated LED lighting. The microscope was positioned at a 30–45° angle based on operator ergonomics. The chamber floor was inspected visually, and prior methods—including canal probing, ultrasonic refinement, and irrigation—were repeated under enhanced magnification. If unsuccessful, the final step IV was initiated.

Step IV: Combined DOM and MHN Mode

If the MB2 canal was not located in the first three steps, a combined approach was employed using both the DOM and MHN mode. This integration of magnified visualization and electronic detection was aimed at enhancing accuracy in challenging cases.

In instances where the canal was still not located, CBCT images were obtained. If the MB2 canal was visible on CBCT images, a secondary diagnostic evaluation was conducted using previously applied techniques. If the canal remained undetectable both clinically and radiographically, it was considered absent.

When necessary, cone-beam computed tomography (CBCT) imaging and supplementary diagnostic evaluations were employed as the reference standard to confirm MB2 canal presence and location. The operator performing the diagnostic procedures was blinded to the CBCT findings during the entire clinical process. CBCT scans were obtained only in cases where the MB2 canal could not be detected after completion of all diagnostic steps and were evaluated by an independent examiner to serve as the reference standard.

Calculation of the Difficulty Coefficient (DC) and the Weighted Diagnostic Efficiency Index (WDEI)

To evaluate the diagnostic performance of each sequential method used in this study, a stratified descriptive analysis was conducted for all four diagnostic steps. The effectiveness of each method was assessed using the Weighted Diagnostic Efficiency Index (WDEI), a composite metric that incorporates both the clinical difficulty associated with each diagnostic step and its success rate in detecting the MB2 canal.

The WDEI was calculated as follows:

WDEI=Stratified Success Ratio×DC

Where:

Stratified Success Ratio: Proportion of successfully identified MB2 canal orifices within each diagnostic step, relative to the number of cases reaching that step.

DC (Difficulty Coefficient): A numerical representation of the relative diagnostic difficulty of each step, calculated using the formula:

The DC was calculated using the following formula:

$DC = (F_i / K_i) \div (N_i / T)^{-1}$,

With:

- F_i: Cumulative number of unsuccessful diagnostic attempts prior to reaching step *i*
- K_i: Number of patients who progressed to step *i*
- N_i: Number of patients evaluated at step *i*
- T: Total number of patients included in the study

The WDEI score thus reflects not only the raw diagnostic yield but also adjusts for the inherent difficulty associated with detecting MB2 canal orifices at each sequential step. Higher WDEI values indicate greater diagnostic utility when accounting for procedural difficulty.

Statistical analysis

Six participants were excluded from the final analysis, as reference diagnostic methods confirmed the absence of an MB2 canal in these cases. All statistical analyses were conducted using IBM SPSS Statistics version 22.0 (IBM Corp., Armonk, NY, USA).

The Weighted Diagnostic Efficiency Index (WDEI) scores for the four diagnostic steps were calculated and compared. The Kruskal–Wallis test, followed by Dunn's post hoc test, was used to assess the relationship between patient age and the diagnostic step at which the MB2 canal orifice was detected.

For nominal variables, including success rates across stages, the chi-square test was applied. A p-value less than 0.05 was considered statistically significant.

3. Results

In root canal retreatment cases, the stratified success ratios for MB2 canal orifice detection across Steps I through IV were 22.6%, 37.5%, 81.7%, and 63.6%, respectively. When these success ratios were combined with their corresponding Difficulty Coefficients (DC), the resulting Weighted Diagnostic Efficiency Index (WDEI) scores were 22.6, 72.5, 119.2, and 716.8 for Steps I through IV, respectively (Table 1).

A total of 124 maxillary molars (comprising 102 first molars and 22 second molars) were retreated. During the initial evaluation using the direct visual method (DVM), MB2 canals were identified in 28 cases. Of the remaining 96 cases, an additional 36 MB2 canals were detected during Step II using the MHN mode of the Dpex X MHN device. From the 60 cases still unresolved, 49 further MB2 canals were identified using the dental operating microscope (DOM) alone in Step III. Lastly, in Step IV, where the DOM and MHN mode were combined, 7 additional MB2 canal orifices were detected (Figure 1). In 4 cases, MB2 canals could not be identified even with CBCT or secondary confirmatory evaluations.

Of all detected MB2 canals, 23% exhibited a separate apical foramen (Type 2-2), while 77% joined the MB1 canal (Type 2-1). No significant differences were found between MB2 canal types and the diagnostic methods employed ($p > 0.05$). Similarly, no significant difference was observed in the detection rates between first and second molars.

The study population consisted of 58 males and 66 females, and no gender-based differences were identified in relation to the diagnostic outcomes ($p > 0.05$). However, a significant association was observed between patient age and diagnostic step, with the mean age increasing significantly across higher diagnostic stages ($p < 0.05$) (Table 2).

4. Discussion

The comprehensive identification and effective management of all root canals are critical to achieving successful outcomes in root canal treatment. In particular, the omission of canals, such as the MB2 canal in maxillary molars, has consistently been implicated in persistent endodontic infections and subsequent post-treatment endodontic disease [21]. Previous retrospective analyses, notably Karabucak et al. [8], highlight that approximately 41% of treatment failures are attributable to overlooked canal anatomy, significantly elevating the risk of persistent periapical lesions.

Although considerable evidence is available that addresses MB2 canal detection during root canal treatments, studies focusing explicitly on root canal retreatment scenarios remain scarce. Root canal retreatments inherently present more complex clinical challenges, including structural alterations from prior instrumentation, dentinal calcifications, and occlusion of canal orifices by root filling materials and restorations [11]. Therefore, evaluating diagnostic techniques in the context of retreatment procedures provides crucial insight into their real-world clinical utility.

The present study implemented a sequential diagnostic approach, facilitating a nuanced assessment of diagnostic effectiveness through progressive complexity. The innovative introduction of the Weighted Diagnostic Efficiency Index (WDEI)—a composite measure that integrates both diagnostic success rates and procedural difficulty—provided an advanced evaluative framework that goes beyond simplistic binary success metrics. Such an approach is essential in appraising endodontic diagnostic tools, reflecting their true clinical value in challenging anatomical scenarios.

The results demonstrated a clear hierarchy in diagnostic efficiency among the evaluated methods. The direct visual method (DVM) predictably yielded the lowest diagnostic accuracy, underscoring its limitations, particularly in cases complicated by secondary intervention factors. In contrast, the combined application of the Dental Operating Microscope (DOM) and the Micro Hole Negotiator (MHN) yielded the highest WDEI scores, highlighting the potential synergy between magnification and electronic impedance-based detection methods. Notably, despite the inherent challenges of the final diagnostic step, which was reserved for particularly difficult cases, the combined approach demonstrated highest adjusted diagnostic efficiency, indicating clinical relevance under complex retreatment conditions. The relatively higher efficiency observed with the combined DOM + MHN method can be attributed to the complementary interaction between optical magnification and impedance-based feedback. While MHN alone detects electrical property variations suggestive of canal openings, DOM facilitates visual confirmation of subtle dentinal landmarks. The concurrent use of both methods thus enables more accurate differentiation between true canal orifices and non-anatomical signal artifacts, particularly in calcified or previously treated teeth.

DOM alone also exhibited significant diagnostic capability, reflecting previous evidence supporting its utility in detecting complex canal anatomy. Enhanced magnification and illumination through DOM have consistently proven advantageous by revealing subtle anatomical structures, such as dentinal map lines, accessory grooves, and orifice locations typically imperceptible with unaided vision [16, 17]. However, the widespread adoption of DOM remains constrained by economic and practical considerations, including substantial financial investment, the requirement for specialized training, and ergonomic challenges [12, 22].

The novel introduction of MHN into clinical practice represents an interesting development, given the paucity of prior literature evaluating impedance-based electronic canal detection in clinical endodontic scenarios. MHN, uniquely designed to detect electrical impedance changes in the pulp chamber, facilitated canal identification even in markedly calcified or structurally altered cases. Its effectiveness, particularly notable in canals that shared common apical foramina (2-1 canal configuration), potentially results from enhanced electrical conductivity following instrumentation of the primary mesiobuccal canal (MB1). Although statistical significance was not established, this promising trend warrants deeper exploration in future studies.

A compelling observation from this study was the relationship between patient age and the complexity of canal detection. The increasing mean age of patients who required advanced diagnostic interventions aligns with known histological changes occurring in root canal systems with aging, including progressive canal obliteration and calcification [23]. This finding underscores the heightened need for sophisticated diagnostic strategies, especially in an aging population.

Gender and molar tooth type did not significantly impact diagnostic success, aligning with existing research that suggests anatomical complexity rather than demographic variables predominantly dictates diagnostic outcomes [24, 25].

The study reaffirmed the supportive diagnostic role of cone-beam computed tomography (CBCT) in root canal retreatment. While CBCT substantially aids clinicians in recognizing hidden canal anatomy, its limitations—such as voxel size constraints, image interpretation variability, and radiation exposure—preclude its routine use as a standalone diagnostic method [19, 26, 27]. Consequently, CBCT should be judiciously reserved as a complementary diagnostic tool when clinical methods fail to locate suspected canal anatomy.

While the current study presents robust clinical data, its sequential diagnostic design represents a limitation. This design reflects real-world clinical decision-making but prevents randomization across all diagnostic modalities. Furthermore, procedures conducted by a single calibrated operator, while eliminating inter-observer variability, may limit generalizability across varying experience levels. Future multicentre trials with multiple operators of differing experience levels may further elucidate the broader applicability of MHN.

5. Conclusions

Within the limitations of this study, the combined use of DOM and MHN demonstrated greater diagnostic efficiency in detecting MB2 canal orifices compared with other methods. DOM alone was highly effective, significantly surpassing conventional visual inspection methods. However, the MHN, a novel, impedance-based diagnostic device, demonstrated substantial clinical utility and represents an accessible and effective alternative or adjunct to magnification, particularly valuable for less experienced clinicians or in resource-limited clinical settings. Future investigations are needed to confirm these preliminary findings, explore the broader applicability of MHN across varying clinical scenarios, and establish standardized training protocols to optimize its implementation in endodontic practice.

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Table 1. MB2 Canal Orifice Detection Across Clinical Stages: Stratified Success Ratios and Weighted Diagnostic Efficiency Index (WDEI)

Stages	Patients Reached	Successful Diagnosis	Stratified Success Ratios (%)	Difficulty Coefficient	WDEI
Stage 1	124	28	22.6	1.00	22.6
Stage 2	96	36	37.5	1.29	72.5
Stage 3	60	49	81.7	2.07	119.2
Stage 4	11	7	63.6	11.27	716.8

Table 2. The Mean Age of Patients for Each Stage

Stages	Number of Detected MB2	Age (Mean±SD)	Minimum	Maximum	p-value
Stage 1	28	$(28.36 \pm 4.35)^{a}$	19	44	< 0.05
Stage 2	36	$(32.64 \pm 3.48)^{b}$	25	39	
Stage 3	49	$(39.14 \pm 5.52)^{c}$	30	50	
Stage 4	7	$(45.71 \pm 3.35)^{c}$	41	49	

Kruskal–Wallis and Dunn's post hoc tests, different superscript letters show a significant difference between groups

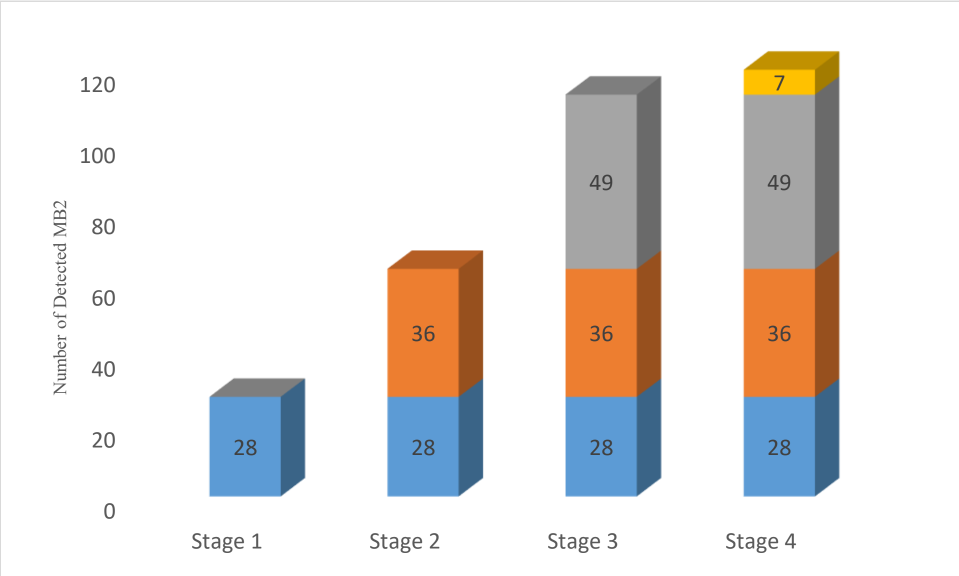

Figure 1. The Clinical Detection Frequencies of MB2 Canal Orifices for Each Stage