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REVIEW ARTICLE

The Role of CBCT in Detection of MB2 in Maxillary First Molars: A Review

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ABSTRACT

The permanent maxillary first molar is a tooth known for its complex and variable root canal anatomy. One of the most common causes of nonsurgical endodontic retreatment is the presence of a missed canal, which is often associated with persistent periapical pathology. Traditional two-dimensional radiographic imaging has limitations in accurately visualizing the intricate internal anatomy of teeth. In contrast, cone-beam computed tomography (CBCT) provides three-dimensional imaging that allows for a more precise evaluation of root canal configurations. A comprehensive literature search was conducted using PubMed, Google Scholar, and ResearchGate databases for studies published between 2006 and December 2024 to evaluate the role of cone-beam computed tomography (CBCT) in detecting the MB2 canal in maxillary first molars. Conclusion: CBCT is a valuable tool for detecting and mapping the mesiobuccal root canal system of the maxillary first molar. Its use can significantly enhance the accuracy of diagnosis and treatment planning, thereby improving the overall quality of root canal therapy.

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1- INTRODUCTION

Successful management of endodontic problems depends on diagnostic imaging techniques to provide the critical information about the teeth under examination their surrounding anatomy. The integration of clinical inspection and diagnostic imaging forms the basis for endodontic diagnosis and decision making and treatment planning, and outcome assessments [1]. Permanent maxillary first molars are typically regarded as have three roots and four root canals because the mesiobuccal root has a second canal. The root canal system's lateral ramifications and apical delta may develop, increasing the likelihood that untreated spaces may remain after root canal therapy. Permanent maxillary first molar is the tooth with the high anatomical variation [2]. Missed canal is one of the reasons for nonsurgical endodontic retreatments and associated with periapical pathology [3]. The success of endodontic treatment is depended on informed of the anatomy of root canal systems. When endodontic treatment fails to find, clean, shape, and obturate the root canals, endodontists face a problem that is posed by the complicated dental anatomy and one of the greatest risk factors for the persistence or development of periradicular disease. The internal anatomy of the maxillary molars is particularly complicated due the frequent occurrence of three roots and four canals in these teeth. The mesiobuccal root (MB) usually contains a second canal known as MB2 [4].

One of the studies have shown that cone-beam computed tomography (CBCT) is an essential tool for determining the second mesiobuccal (MB2) canal in maxillary molars when assessing the root canal anatomy, many divergent techniques that can describe the root and root canal morphology that facilitate the localization of accessory canals in maxillary first molars reducing the failure and the necessity of the retreatment of the root canals are available. [5]. The review aims to explore and compile the various reported techniques used for analyzing the root canal morphology of maxillary first molars, with a particular focus on identifying the second mesiobuccal canal (MB2). This review emphasizes the role of cone-beam computed tomography (CBCT) as a three-dimensional diagnostic tool in assessing root canal variations, enhancing the detection of MB2 canals, and evaluating their prevalence across different populations. The ultimate goal is to improve diagnostic accuracy, treatment planning, and clinical outcomes in endodontic therapy.

2- METHODOLOGY

2.1 Search Strategy

A comprehensive literature search was conducted using PubMed, Google Scholar, and ResearchGate databases to identify relevant studies related to the detection of the second mesiobuccal canal (MB2) in maxillary first molars using cone-beam computed tomography (CBCT). The search included studies published between January 2006 and December 2024.

2.2 Inclusion Criteria

The inclusion criteria were set to identify relevant, high-quality evidence on detecting the MB2 canal in maxillary first molars. Eligible studies were English-language articles published in peer-reviewed journals from 2006 to 2024, ensuring accessibility and scientific rigor. Clinical, in vitro, retrospective, and review articles were included, provided that they specifically examined cone-beam computed tomography (CBCT) for assessing root canal morphology and identifying the MB2 canal. This brought together direct findings and contextual evidence on CBCT's diagnostic utility for this anatomical variant.

2.3 Exclusion Criteria

Strict exclusion criteria were also used to keep the review focused and methodologically sound. Duplicate publications were removed because they would create redundant data. Non-English articles and conference abstracts were left out because of language barriers and the preliminary status of unpublished findings. Studies unrelated to CBCT technology or MB2 canal detection did not meet the review's specific objective and were excluded as well. Articles without enough methodological detail were discarded, so that every included study provided adequate transparency and reproducibility and the review's conclusions rested on a stronger basis.

2.4 Study Selection and Data Extraction

Titles and abstracts of the identified studies were screened initially. Full-text articles that met the inclusion criteria were then assessed for eligibility. Relevant information regarding study design, population, CBCT findings, and prevalence of MB2 canals was extracted and summarized.

2.5 Quality Assessment

The included studies were evaluated according to their methodological quality, relevance to the review topic, clarity of imaging methodology, and adequacy of reported outcomes. Studies with insufficient scientific reliability were excluded from the final review.

3- MAXILLARY PERMANENT FIRST MOLARS

The permanent first molar teeth are among the initial teeth to emerge in the mouth and are therefore highly likely to require root canal treatment [6].

3.1 External anatomy of maxillary Permanent First Molars

- **Crown morphology**

The largest tooth in the maxilla is the permanent first molar tooth. The buccolingual and mesiodistal dimensions of the anatomical crown of the maxillary first molar are wider. Furthermore, the extensive surface area of the occlusal table facilitates the mastication of food due to the crown being wider both from front to back and side to side compared to premolars, and slightly shorter than premolars. The maxillary permanent first molar contains a total of five cusps, four of which are well-developed. The cusps referred to are the mesiobuccal, mesiolingual, distobuccal, and distolingual cusps. The fifth cusp is rudimentary, seen as a trivial additional cusp with minimal physiological significance [7].

- **Root morphology and number of roots**

The well-developed and widely spread roots of the permanent maxillary first molar provide it with the strongest anchorage in the maxillary arch. This tooth's typical root structure consists of the palatal, mesiobuccal, and distobuccal roots. The palatal root exhibits a conical and almost rounded morphology. The mesiobuccal tooth root has a broader buccolingual dimension and is more resilient to rotational forces. The distobuccal root is the smallest form of root, characterized by a rounded and smooth cross section. Among the three, the palatal root is the longest, while the other two roots are nearly equal in length [8]. According to the study and the clinical experience, the MB2 is commonly located in the developing groove, approximately midway between the MB1 and the palatal orifices [9].

3.2 Internal anatomy of permanent maxillary first molar

- **Pulp chamber and canal entrances**

The only part of the tooth that extends further towards the crown is the pulp horns, which keeps most of the pulp chamber inside the root stem. When comparing the dimensions, the pulp chamber is larger in the buccolingual direction than in the mesiodistal direction. Calcification may cause significant reduction in the capacity of the pulp chamber. The distobuccal canal orifice is situated at the apex of the triangle, whereas the orifice of the mesiobuccal canal is positioned at the base of the triangle. The canal openings of the maxillary first molars are positioned in a triangular pattern inside the pulp chamber. The palatal canal orifice is situated at the lingual midpoint. The distobuccal canal is situated in a position that is both distant and palatal to the mesiobuccal canal. Additionally, it is adjacent to a sharp corner of the pulp chamber. The second mesiobuccal canal (MB2), if it exists, is found at or slightly towards the front of the imaginary line that connects the mesiobuccal and palatal canals. It is situated towards the back of the mesiobuccal canal [10].

- **The canals morphology**

The portion of the pulp space that is located in the roots of a tooth is referred to as the root canal. The mesiobuccal canal is characterized by a spherical shape and a significantly tiny diameter at its end. Additionally, it exhibits an oval or flat oval cross-sectional shape. The pulp chamber's floor, situated close to the cervical line, features a funnel-shaped opening that terminates at one or more apexes of the foramina. The foramina are located either at or adjacent to the anatomical apex of the root [11].

3.3 Differences in the anatomy of the root canals

- **Different numbers of palatal and distobuccal root canals**

The distobuccal root commonly presents with a single canal and a single apical foramen in the majority of maxillary first molars. Similarly, the majority of palatal roots have only one canal and foramen., as reported in previous anatomical studies [6].

- **MB2 frequency variations in maxillary first molars**

Due to dentin apposition, the canal narrows with age, it has been demonstrated that the prevalence of MB2 declines with age [12].

- **MB2 is detected bilaterally in the maxillary first molars**

Contralateral maxillary first molars in different groups often develop MB2 root canals. From a clinical standpoint, it is important for the clinician to be aware of the higher probability of MB2 formation in the patient's opposite molar if they are aware that MB2 has been previously identified in one of the maxillary first molars [13] as shown in (figure 1).

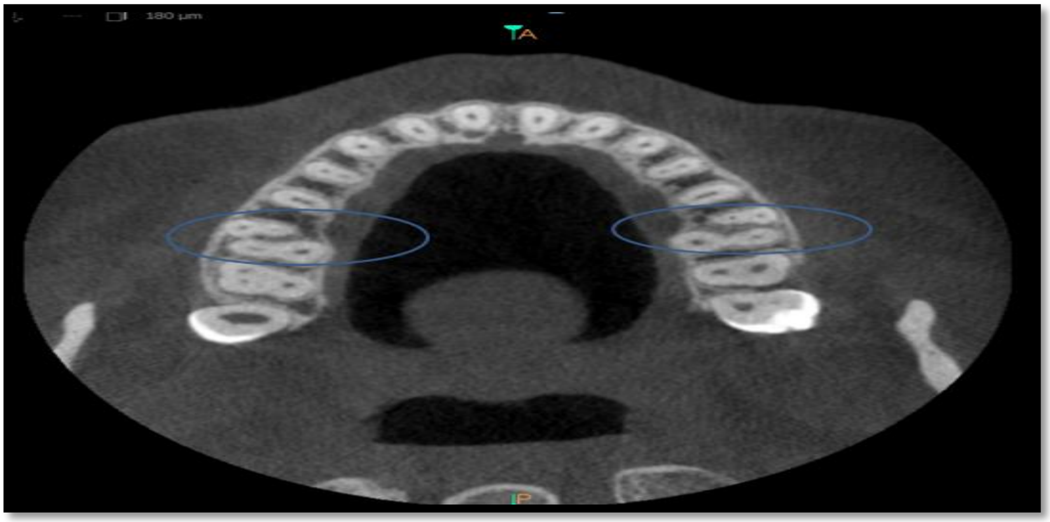

Fig (1): Schematic representation of the bilateral presence of the MB2 canal in maxillary first molars

4- METHODOLOGY OF STUDYING INTERNAL AND EXTERNAL DENTAL MORPHOLOGY

The complex anatomy of the root canal system has always been a challenge for endodontists and researchers. Many studies have examined the anatomy of root canals in permanent teeth using different methods and technique [14].

4.1 In vitro modalities

- **Histologic sectioning**

For the purpose of visualizing the anatomy of root canals in human teeth, various methods have been developed, one method includes treating the extracted teeth with acids for weeks, then sectioning it at multiple intervals, and then staining sections with hematoxylin to see root canal morphology clearly under a magnification power [15].

- **Clearing and staining**

Clearing and staining procedures start with preparation of an access opening for the study teeth. This is followed by injection of the staining ink coronally into the root canals, allowing the ink to flow through the canals in an apical direction [16].

- **Contrast-enhanced radiography**

This method involves introducing a low-tension medium into the root canal system of the examined teeth to improve their visibility on a conventional radiograph [17].

- **Micro-computed tomography**

This method can illustrate both internal and external dental anatomy using reconstructed 3D images, providing quantitative as well as qualitative data.

4.2 In vivo modalities

- **Two-dimensional imaging**

In this type of radiography, there are four main types of images: traditional periapical radiograph, digital periapical radiograph, occlusal radiograph, and panoramic x-ray. For each, there are suitable indications and properties with respect to the coverage area, power of resolution, and capturing technique [18].

- **Three-dimensional imaging**

Following the development of computerized transverse axial scanning by Hounsfield GNJT [19] computed tomography (CT) was introduced. CBCT technology has been utilized in the diagnosis, treatment, and retreatment sessions of various situations with varying levels of complexity. It is suitable in a wide range of dental areas [20].

5- CONE BEAM COMPUTED TOMOGRAPHY

A three-dimensional radiograph is used for the purpose of diagnosing and planning dental treatment. CBCT provides clear visualization of the head and neck tissues without any overlapping, facilitating the radiologist's identification of landmarks. CBCT technology provides improved spatial resolution and significantly reduces radiation exposure. It has successfully transformed dental imaging from 2D to 3D, thus overcoming limitations such as magnification, distortion, superimposition, and misrepresentation of anatomical components [21].

5.1 Basic principles of CBCT machine

CBCT utilizes a reciprocating solid-state flat panel detector that undergoes turning full 180-360 degrees around the patient, capturing images of the specified anatomical volume, such as the total dental/maxillofacial area or a specific regional area of interest. The scan duration of CBCT devices might vary between around 5 and 40 seconds, depending on the manufacturer. Most CBCT equipment is equipped with easy-to-use viewing software that contains basic 3D imaging tools [22].

5.2 Types of CBCT technique

CBCT systems can be categorized based on the orientation of the CBCT during image capture, the extent of the patient's scan volume exposed to radiation, or the clinical utility. The patient can be positioned in one of three ways, depending on the technology utilized for maxillofacial CBCT: sitting, standing, or lying down. Patients with physical limitations may have difficulty using equipment that requires them to lie flat on their back due to its larger physical size. It is possible that stationary units may not be adjustable to a height that is accessible for patients who use wheelchairs. The most comfortable units are those equipped with seating. However, fixed seating may hinder the efficient screening of physically challenged individuals or those bound to wheelchairs. The field of view [FOV] or scan volume is primarily determined by the volume, size, and shape of the detector, the beam projection geometry, and the ability to collimate the beam. The field of view [FOV] can take the shape of either a cylinder or a sphere. The main purpose of collimating the X-ray beam is to minimize the exposure to X-rays in the specific area of interest. The limitation in field size allows for the selection of the optimal field of view [FOV] for each patient, taking into consideration their specific disease presentation and the area that needs to be scanned. According to a chosen or available scan [23].

5.3 Classification of CBCT units according to the FOV:

Shown in (Figure 2)

- Large FOV scans provide images of the entire craniofacial skeleton, enabling cephalometric analysis.
- Medium FOV scans image the maxilla or mandible or both.
- Focused or restricted FOV scans provide high resolution images of limited regions.
- Stitching multiple small FOV scans allows imaging of larger regions [24].

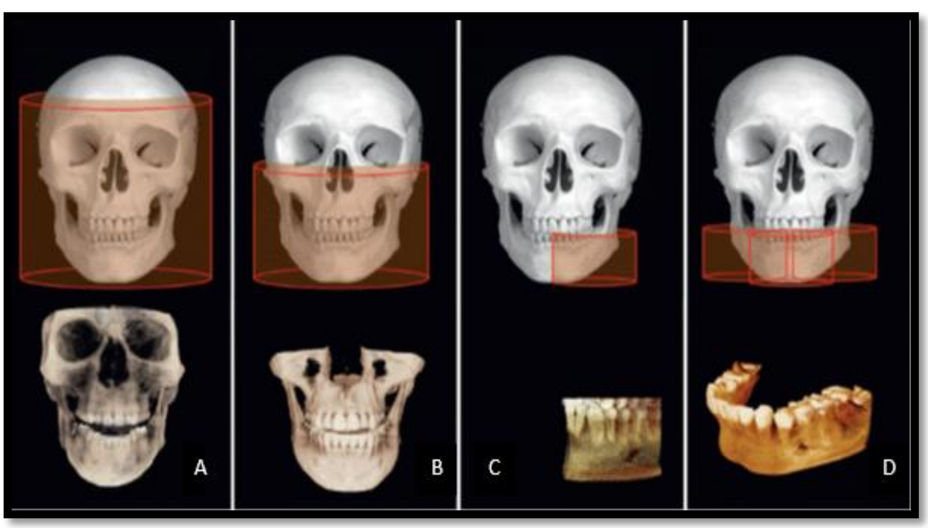

Fig (2): Classification of the CBCT units on the basis of FOV. Large FOV (A), medium FOV (B), focused (small) FOV (C), stitching of multiple focused scans (D)

5.4 Advantages of CBCT

CBCT technology offers advantages for craniofacial imaging compared to traditional CT [25]

- X-ray beam limitation, Image accuracy, Rapid scan time, Dose reduction, Reduced image artifact, Image accuracy, Economical, and comfortable and safe.

5.5 Disadvantage of CBCT

- Scatter, Motion artifact due to increased scan time, and Poor contrast resolution, resulting in inability to evaluate soft tissue [26].

5.6 Limitations of CBCT

- An artifact refers to any distortion or error in an image that is not relevant to the issue being studied. This reduces the quality of CBCT images and prevents the dento-alveolar region's structures from being adequately visualized.
- Image noise results from extensive interactions with tissues during CBCT scanning, which results in a huge volume of scattered radiation.
- CBCT devices offer considerably less soft tissue contrast than traditional CT scanners, which results in poor soft tissue contrast [27].

5.7 CBCT and Endodontics

CBCT is more effective than two-dimensional radiography for diagnosing periapical lesions. This enables the visualization of lesions that are in close proximity to the maxillary sinus, affect the membrane of the maxillary sinus and near the mandibular canal. CBCT enables an improved visualization of the course of these fractures, which are commonly at an angle, and the link between the fracture, pulp, periodontium, and crystal bone. This, in turn, helps in managing the fractures more effectively. A small-sized cone beam computed tomography (CBCT) scan can be used for endodontic purposes. It allows for the examination of root canals in teeth and a comprehensive analysis of the canal's trajectory, including any curved areas or splits. CBCT has enhanced the efficacy of endodontic therapy by enabling the detection of accessory root canals, leading to improved success rates [28] as shown in (Figure 3).

Fig (3): CBCT image demonstrating the application of cone-beam computed tomography in endodontic diagnosis and detection of root canal morphology

5.8 CBCT and complex root canal anatomy

The inability to detect and clear the MB2 canal resulted in the unsuccessful completion of endodontic treatment on the maxillary first permanent molars. It is crucial to identify additional root canals in order to ensure the efficacy of root canal treatment. The utilization of CBCT examination has enhanced the capability to diagnose MB2 canals. This imaging technique allows for the visualization of an image from multiple perspectives, with highly precise slices, without interfering with the overlapping structures. The identification of MB2 canal artifacts, which can negatively impact the quality of scans, is affected by factors such as root filling and voxel size. However, there is limited evidence available to substantiate these assertions [29].The maxillary first molar has the greatest tooth volume and the most complex root canal morphology. It is considered the posterior tooth that is most commonly treated but least comprehended. The first permanent maxillary molar and second permanent maxillary molar is the molars with the most intricate and diverse root canal systems [30].

6- SECOND MESIAL CANAL PREVALENCE IN MAXILLARY FIRST MOLARS

According to histological and radiographic studies, the prevalence of the MB2 canal in maxillary first molars varies widely, ranging from 18% to 96%. This variation may be attributed to differences in study populations, age groups, ethnic backgrounds, sample sizes, and diagnostic techniques such as CBCT, microscopy, and histological sectioning. They interact often with one another along their lengths, and more than 58% of the time, they come to an end in two or more exit portals. The pulp system's second mesiobuccal entry is often found in the developing groove, parallel to the mesial marginal ridge, and roughly midway between the MB1 and the palatal orifice. The physician must advance pursuing medially into the pulpal floor as opposed to apically in order to find the MB2 because all orifices begin on the pulpal floor and roughly lay on the same plane. It is possible for the MB2 orifice to be lingually dislocated away from the MB1 orifice and toward the palatal orifice [31].

The typical technique that has been used to detect root canals is Naked-eye examination. Endodontic practice has incorporated tools including cone-beam computed tomography (CBCT)and microscopes. Microscopes are magnifying instruments that can be utilized in dental offices and improve canal orifice detection [32]. A second mesiobuccal canal has been observed to occur somewhere between 40% and 95% of the time. According to Gu et al., (2010), [33],14.0% of maxillary first molars had two distinct canals with separate apical foramens, 37.5% had two canals that combined, and 48.5% had a single canal. According to Apoorva, 2011) [34], there were two mesiobuccal roots in 71.2% of maxillary first molars; of these, 31.7% had two apical foramen and 39.4% had two canals that connected. The occurrence of MB2 in the MB root of maxillary molars was researched by Somma *et al.*, (2009) [35]. The frequency of MB2 canals was higher in the maxillary first molars (73.2%), lower in the maxillary second molars 950.7%), and lowest in the maxillary third molars (20.0%). The maxillary first molars had a larger incidence of separate MB2 canals (54.9%) than the maxillary second molars, while all of the maxillary third molars had linked MB2 canals. Even for a competent endodontist, navigating the MB2 canal can be exceedingly difficult. The MB2 canal typically exhibits a notable mesial gradient in the coronal 1 to 3 mm, just apical to its mouth. When MB2 is instrumented, the file's tip frequently bumps into the canal's mesial wall and is unable to advance apically. The issue is made worse by the MB2 canal's smaller size and typical higher level of calcification than MB1. The access needs to be rhomboidal in shape to enable the requisite mesially directed shaping for its position and instrumentation. A rhomboidal access cavity was created to investigate the extra MB2 root canal, which CBCT has proven is present [36] .The incidence of a second root canal in the mesiobuccal root (MB2) is 56.8%, in the distobuccal root 1.7%, and in the palatal root less than 1% [37] as shown in (Table 1).

Table (1): Studies suggest that the maxillary first molars commonly have the MB2 canal within their population

Number of Canals in the Maxillary First Molar	Population	Maxillary first molar canal count
The prevalence of MB2 canal was 44%	Brazilian	314
MB2 proportion in USA was 64.8%	Indian	250
50.8% samples had MB2 canal	Australian	250
MB2 canal was found in 80.1% of all examined samples	Emirati	261
71% of maxillary first molars had a mesiobuccal root with two roots.	Caucasian	542
A review of CBCT volumes found the presence of an MB2 canal 69% of the time.	American	100
The presence of the MB2canal in maxillary first was 32.5%	Chilean	802
30.9% maxillary molars had the additional canal in the mesiobuccal roots,	Chinese	630
Additional canal (MB2) was detected in 86.6% of mesiobuccal roots	Iranian	149

Abbreviations: MB2 = second mesiobuccal canal; CBCT = cone-beam computed tomography

7- DIFFERENT TECHNIQUES ARE AVAILABLE TO HELP DENTISTS IN LOCATING MB2 CANALS

- Naked eye examination (Visual method)
- Operating microscope (Magnification method)
- Digital radiograph (Radiographic method)
- Ophthalmic dye strip (Dye method)
- CBCT
- Cross-sectioning [32]

7.1 Visual method

In the region of the maxillary first molar, lignocaine hydrochloride 2% local anesthetic was administered. The rubber dam was used. Large round bur was used to begin access cavity preparation, and then non-end-cutting bur. The dentin's mesial shelf was removed, and the access cavity was modified to take on its usual shape. In order to debride the pulp tissue, an endodontic excavator was used. We irrigated the access cavity with 3% sodium hypochlorite. After drying the pulp chamber, the dentinal map was used to identify the root canal opening. With the assistance of the endodontic explorer, root canals were discovered [38].

7.2 Magnification method

Operating microscope would be regarded as the valuable aid for the detection of the MB2 canal because it has the highest magnification compared to the other tools utilized in the investigation. As the "gold standard," an operating microscope with an 8x magnification was utilized to find the MB2 canal in the maxillary first molar [39] as shown in (figure 4).

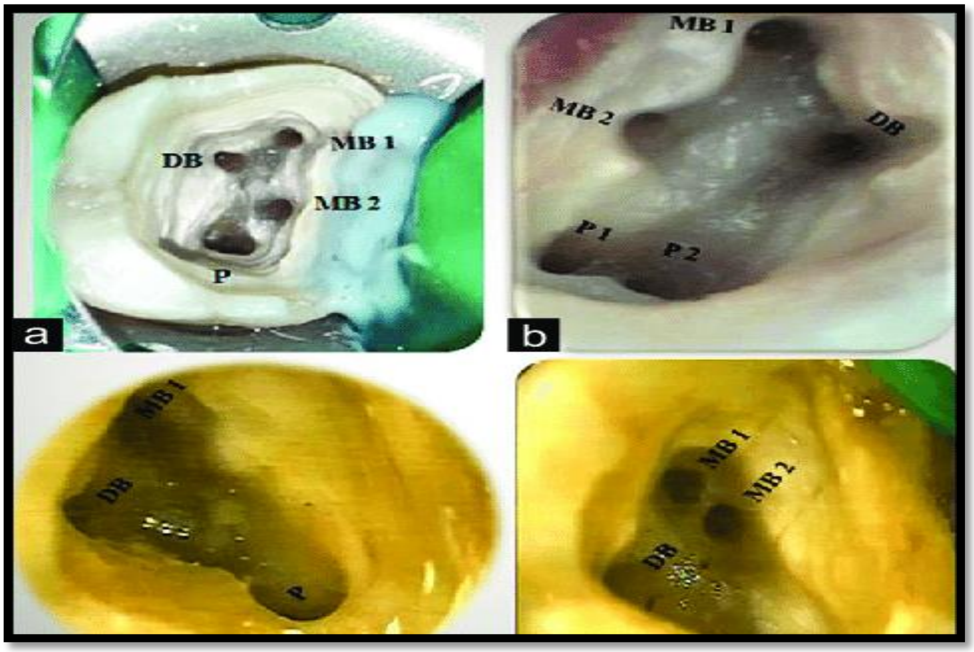

Fig (4): MB2 canal location with magnification technique

7.3 Radiographic method

The maxillary first molar was digitally radiographed using the bisecting angle method. A second radiograph was taken using angulation in the mesial. Next, the initial observer was instructed to identify the MB2 canal on both radiographs as shown in (Figure 5) [36].

Fig (5): Detection of MB2 canal using digital radiograph

7.4 Dye method

The area of interest was dyed using an ophthalmic dye strip. An ophthalmic dye strip (usually containing fluorescein) is dipped into a saline solution and collected in a dappen dish. The dyed solution is placed into the pulp chamber and left in the access cavity for about 3 to 5 minutes. The organic connective elements of any remaining pulpal tissue and the boundaries of the canal orifices readily absorb the dye. A blue curing light (or operating microscope equipped with a cobalt blue filter) is directed toward the area. When illuminated, the absorbed dye exhibits a bright, fluorescent, greenish-yellow color. The dye fluoresces sharply against the surrounding monochromatic dentin, creating a visual "roadmap" that distinguishes the pulp chamber floor from the root canal orifices [36], As shown in (figure 6).

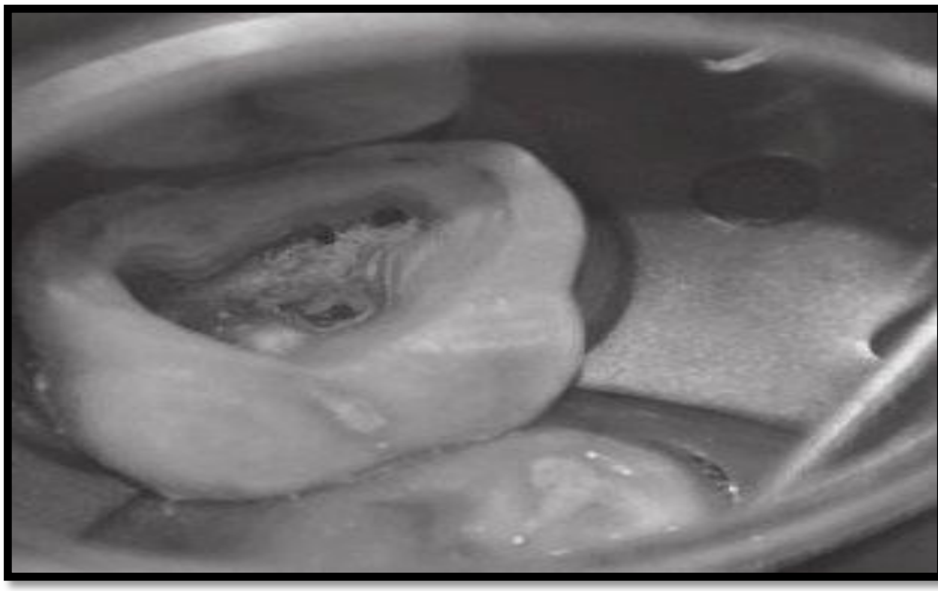

Fig (6): MB2 canal location using the dye method

According to the study's findings, the percentage of MB2 canals found in maxillary first molars was most frequently found using a microscope to operate (87%), following the radiographic approach (19%), optical method (73%), and dye method (28%). The comparison of MB2 canals found in maxillary first molars using the aforementioned methods has been provided. In this study, it was found that using the "Z" test to compare two proportions, the radiography and dye approaches did not differ much from one another, but there was a very significant difference between radiographic and visual methods for detecting the MB2 canal in the maxillary first molar.

A study done by Alzien *et al.*, (2020) [32] showed that microscope method was more accurate than the naked eye method in the detection of MB2, However, in comparison to cross-sectioning, the difference was statistically significant. On the other hand, the CBCT method showed high accuracy for locating MB2 canals in the first maxillary molars. The study's findings showed that, the accuracy of CBCT in detecting MB2 canal was 93.8%, naked eye and microscope showed accuracy of 21.7% and 71.4% respectively. Cross-sectioning (the reference standard) successfully recognized MB2 in (94.23%) of the samples, outperforming identification by the naked eye (20.5%), the microscope (67.3%), and CBCT (88.6%). Cross-sectioning demonstrated the highest detection rate for MB2 canals and is considered a reference standard in ex vivo anatomical studies because of its direct visualization of internal canal morphology. However, this technique is destructive and cannot be applied clinically. In contrast, CBCT showed high diagnostic accuracy and remains the most reliable non-invasive in vivo imaging modality for the clinical detection of MB2 canals in maxillary first molars. The difference in MB2 detection between naked eye and microscope approaches was further influenced by the removal of excess dentin from the canal openings using ultrasonic tips. On the other hand, not all samples may have had calcifications above the MB2 eliminated by the modest apical pressure of the ultrasonic tip. Compared to naked eye and microscope approaches, CBCT was a more accurate and reliable way to find MB2 canals as shown in (figure 7).

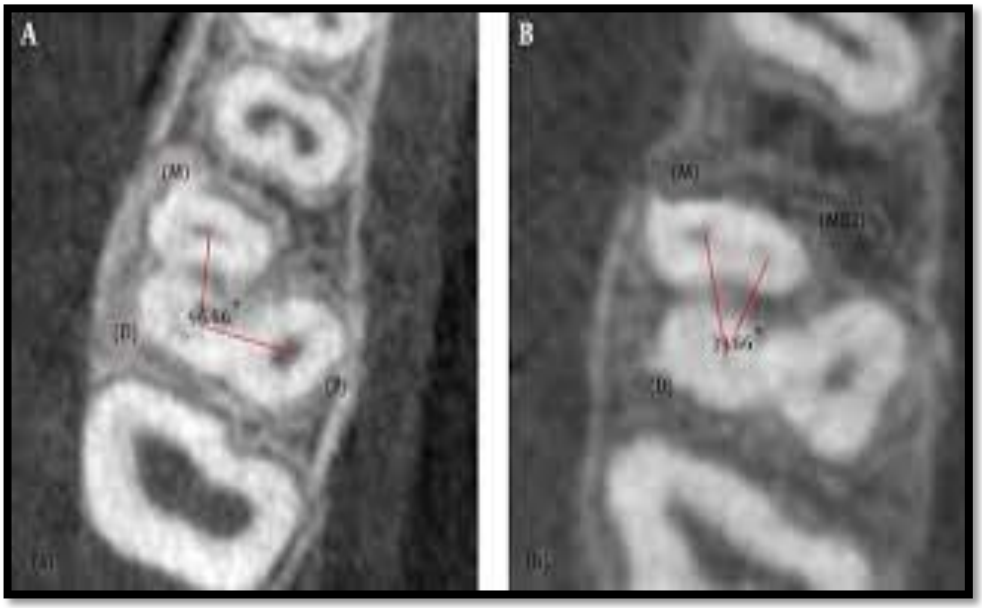

Fig (7): Location of MB2 canal with CBCT

8- CONCLUSION

Cone beam computed tomography is a helpful tool to have in the endodontist's toolbox for counting root canals or finding ones that were missed. It has greater mean values of specificity and sensitivity since it is possible to control the cuts in various schemes. compared to standard radiographic techniques. This enhances its clinical utility in diagnosis or in retreated endodontic cases, especially when surgery is planned, and possibly as a first line of defense prior to treating the tooth to prevent leaving any canals untreated. The present classifications do not adequately capture the intricacy of the mesiobuccal root morphology of the maxillary first molar teeth.

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