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CBCT ANALYSIS OF ROOT CANAL PATTERN IN THE MESIOBUCCAL ROOT OF MAXILLARY FIRST AND SECOND MOLARS

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ABSTRACT

Aim: Analysis of root canal pattern in the mesiobuccal root of maxillary first and second molars using CBCT.

Methods: In this study fifty human extracted teeth with fully formed apices were selected (twenty five maxillary first molars and twenty five maxillary second molars). CBCT was used to evaluate the presence of the MB2 (mesiobuccal) root canal and the morphology of root canals in MB root (the type of root canal system).

Results: CBCT examination showed that out of 25 maxillary first permanent molar teeth studied, the mesiobuccal roots with a single canal were of type I (56%) or type III (4%) configuration. Those with two canals were of type II (24%) or type IV (16%) configuration. Regarding the maxillary second permanent molars the mesiobuccal roots were with a single canal of type I (64%) configuration. Those with two canals were of type II (12%), type IV (20%) or type VI (4%) configuration.

Conclusion: CBCT scans certainly show promise as a modality to facilitate the identification of root and canal configuration. The information gained about the tooth anatomy and canal morphology before treatment could potentially facilitate root canal therapy.

KEYWORDS: CBCT, mesiobuccal root canal, root canal pattern, maxillary first molar, maxillary second molar.

INTRODUCTION

The success of nonsurgical root canal therapy (NSRCT) is dependent on thorough biomechanical instrumentation, effective chemical debridement, and hermetic obturation of the root canal system. To achieve these goals, a complete knowledge of basic root canal morphology and its variation is absolutely necessary for every dentist before performing the endodontic treatment. Incorrect identification of the number of roots and root canals usually results in endodontic treatment failure [(1)].

Permanent maxillary molars typically have 3 roots (mesiobuccal, distobuccal and palatal). Reports on variations with respect to number of

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roots and canals are not rare in dental literature. Previous morphological studies on maxillary molars usually focused on the presence of the fourth canal (MB2) in the mesiobuccal roots, as well as the complex canal forms in the fused roots. Only very few clinicians were aware of the 4-rooted maxillary molar due to its low incidence. The extra root and canal may lead to treatment failure if clinicians fail to identify its presence, or manage it improperly. It was reported that remnants of pulp tissue can be a reservoir for the growth of microorganisms, which may affect and compromise treatment outcomes. Therefore, the ability to locate all canals in the root canal system is an important determinant of successful endodontic treatment [2-5].

During the diagnosis and treatment phases of the maxillary molars, a clinician must be aware of anatomical variations. The mesiobuccal root of the maxillary first molar has, perhaps, been studied and written about more than any other in the endodontic literature. The MB-2 canal can be negotiated in 80% of maxillary molars. Although an orifice is apparent in 96% of the teeth, the ability to negotiate MB-2 is facilitated by an operating microscope. To date, only a few case reports have reported locating and obturating a third canal in the mesiobuccal root of the permanent maxillary first molar [6].

The significance of canal anatomy has been underscored by studies demonstrating that variations in canal geometry before shaping and cleaning had a greater effect on changes that occurred during preparation than instrumentation techniques. Together with diagnosis and treatment planning, a better knowledge of the root canal system and its frequent variations is an absolute necessity for a successful root canal treatment [7].

The root canal systems were classified according to the classification of **Vertucci 2005** [8] as follows: Type I: one single root canal extending from the pulp chamber to the apex. Type II: separate root canals leaving the pulp chamber and joining short of the apex to form one canal. Type III: one root canal leaving the pulp chamber before dividing into two canals within the root and then merging to exit as one single canal. Type IV: two separate root canals extending from the pulp chamber to the apex. Type V: one root canal leaving the pulp chamber and dividing short of the apex into two separate and distinct root canals with separate apical foramina. Type VI: two separate root canals leaving the pulp chamber, merging in the body of the root, and again dividing short of the root apex to exit as two separate and distinct canals. Type VII: one root canal leaving the pulp chamber, dividing and rejoining within the body of the root canal and finally re-dividing into two distinct canals short of the apex. Type VIII: three separate and distinct root canals extending from the pulp chamber to the apex **(Fig.1)** [9].

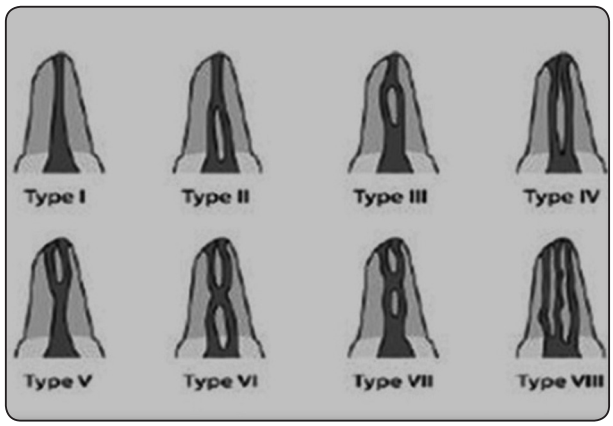

Fig. (1) Diagrammatic representation of Vertucci's canal configurations (2005).

In recent years, cone-beam computed tomography (CBCT) has been clinically used to evaluate the root and canal anatomy because of its high resolution and noninvasion. It differs from conventional CT imaging in that the whole volume of data is acquired in the course of a single sweep of the scanner. Therefore, the scanning time and the dose of radiation can be significantly reduced. CBCT allows for *in vivo* studies of the root variations in human dentitions [3, 5].

Cone beam computed tomography (CBCT) is a technique that produces 3-D digital imaging at reduced cost and less radiation for the patient than traditional computed tomography scans. Other advantages of CBCT are easier image acquisition, higher image accuracy and reduced artifacts. Studies have suggested that CBCT provides accurate and reliable linear measurements for reconstruction and imaging of dental and maxillofacial structures. The X-ray area of interest is limited by the action of collimation of the CBCT primary X-ray beam. Limiting the irradiation field to fit the field of view (FOV) with a reduced exposure of set dosage to the patient in addition to an improved image quality due to reduced scattered radiation allows this function to provide dosage savings. Previous studies evaluated the accuracy of the CBCT system compared with digital periapical radiographs in the detection of vertical root fracture (VRF) [10, 11].

Methodology

In this study fifty human extracted teeth with fully formed apices were selected for CBCT analysis (twenty five maxillary first molars and twenty five maxillary second molars).

Teeth that demonstrated fully-formed roots and intact external morphology (without resorption or cracks) were selected for the study. No specimen with root filling, or history of any endodontic maneuvers or severe crown destruction had been included in the study. After extraction, the teeth were cleaned and debrided of periodontal tissue and calculus by curettes and ultrasonic scalers, washed under running water, blotted dry and stored in saline solution.

A mould was milled from copper sheets of thickness 5 mm into a shape of a cube of 2 x 2 x 2 cm^3 into which the sample teeth were invested. Extracted teeth were collected and each tooth was embedded into the mould which contains cold cure white acrylic resin (Acrostone, cold cure, England) until the level of the cervical line. The sample teeth were left inside the mould for 5-10 min till setting of the cold cure acrylic resin and then removed to form the acrylic blocks which contains the sample teeth. The acrylic blocks were finished using trimmer in order to produce smooth shiny surfaces.

Radiographic analysis of sample teeth with Cone Beam Computed Tomography (CBCT) was used to evaluate the presence of the (mesiobuccal) MB2 root canal and the morphology of root canals in MB root (the type of root canal system).

Scanora 3D was the CBCT machine (Scanora 3D, Soredex, Finland) (**M. Ekram radiodiagnostic center**) used in this study. The detector of this machine was flat panel with isotropic voxel size 133 μm. The X-ray tube used to scan the samples posses a current intensity 15 mA, potential difference 85 Kvp and a focal spot size 0.5 mm. The scanning time was 18 seconds of pulsed exposure resulting in an effective exposure time 3 seconds to scan the field of view (FOV) (sample teeth) of 7.5 cm height x 14.5 cm width.

The Dicom (Digital Imaging and communication in Medicine) files of the scanned teeth were imported to the 3rd party software (**OnDemand 3D**) (Cybermed, South korea). Slice thickness (0.1mm) was selected to examine the three planes of the teeth (Bucco-lingual, Mesio-distal and occlusal/gingival planes).

CBCT evaluation was performed through interpretation of two views

- ***First view (The axial view):***

The slice orientation was adjusted on the axial cut perpendicular to the buccal and lingual height of contours of the teeth at the level of root canal orifices to identify the presence of 2 root canal orifices in the mesiobuccal roots of maxillary 1^{st} or 2^{nd} molars.

- ***Second view (the corrected sagittal view):***

The slice orientation was adjusted on the axial plane traversing to pass through the 2 orifices of the MB root of maxillary 1^{st} or 2^{nd} molars to show the 2 root canals on the sagittal screen. This view reveals the corrected mesiodistal and the vertical planes of the teeth **(Fig.2 and Fig.3)**.

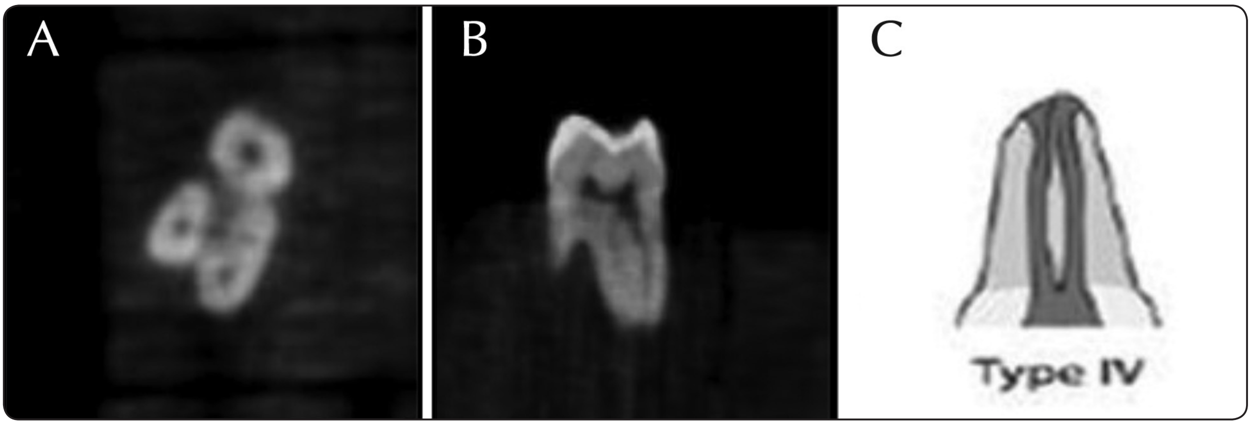

Fig. (2) CBCT image of a maxillary 1st molar showing (A) axial section showing three roots with a MB root showing two openings of two canals. (B) Corrected Sagittal section revealed Type IV Vertucci's in the MB root of a maxillary 1st molar. (C) The corresponding Vertucci's canal configurations (2005).

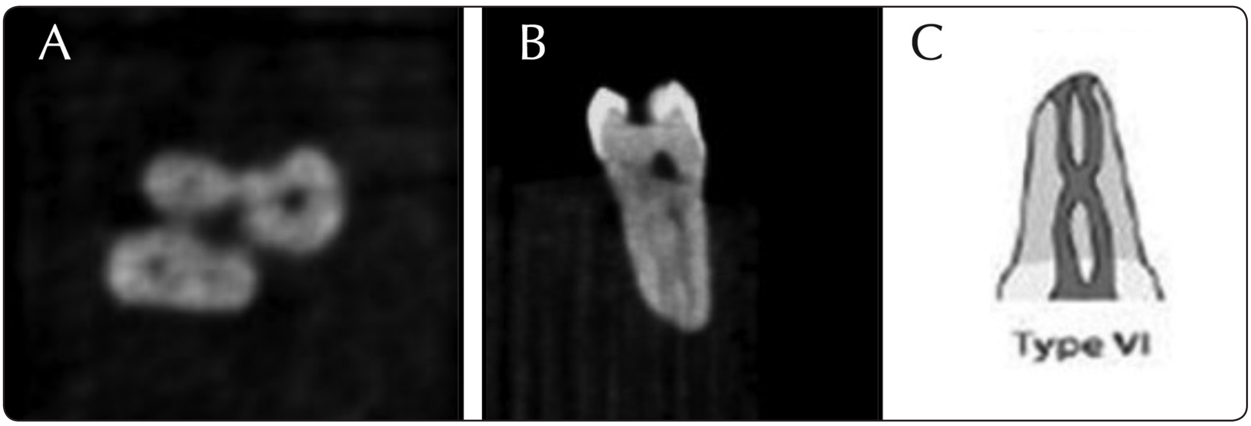

Fig. (3) CBCT image of a maxillary 2nd molar showing (A) axial section showing three roots with a MB root showing two openings of two canals. (B) Corrected Sagittal section revealed Type VI Vertucci's in the MB root of a maxillary 2nd molar. (C) The corresponding Vertucci's canal configurations (2005).

Evaluation of the CBCT views

The axial and corrected sagittal views were evaluated by radiologist and endodontist blindly. Images were then evaluated to identify the presence of the MB2 and the root canal system in the MB root of maxillary permanent 1st and 2nd molars. Results and findings that obtained from both views and from the two viewers were compared to each other. The procedure was repeated after 2 weeks to avoid interobserver and intraobservers errors.

Statistical Analysis

Descriptive statistical analysis was performed in this study by calculating the percentage of MB2 and RCSs (Root canal systems) in the maxillary 1st and 2nd molars identified from CBCT analysis.

Qualitative data were presented as frequancies and percentages. Statistical analysis was performed with PASW Statistics 18.0® (Perdictive Analytics Software).

RESULTS

CBCT examination showed that out of 25 maxillary first permanent molar teeth studied, the mesiobuccal roots with a single canal were of type I (56%) (14 teeth) or type III (4%) (one tooth) configuration. Those with two canals were of type II (24%) (6 teeth) or type IV (16%) (4 teeth) configuration **(Table.1) (Fig.4)**.

TABLE (1) The number of root canals, frequencies and percentages of different root canal systems in MB roots of maxillary permanent 1st molars

Specimens (No)	No of MB root canals		Configuration of root canal systems							
	1	2	I	II	III	IV	V	VI	VII	VIII
Maxillary 1st molar (25)	15 60%	10 40%	14 56%	6 24%	1 4%	4 16%	0	0	0	0

Regarding the maxillary second permanent molar teeth CBCT examination revealed that out of 25 maxillary second permanent molar teeth studied, the mesiobuccal roots of 16 teeth were with a single canal of type I (64%) configuration. Those with two canals were of type II (12%) (3 teeth), type IV (20%) (5 teeth) or type VI (4%) (one tooth) configuration **(Table.2) (Fig.4)**.

TABLE (2) The number of root canals, frequencies and percentages of different root canal systems in MB roots of maxillary permanent 2nd molars

Specimens (No)	No of MB root canals		Configuration of root canal systems							
	1	2	I	II	III	IV	V	VI	VII	VIII
Maxillary 2nd molar (25)	16 64%	9 36%	16 64%	3 12%	0	5 20%	0	1 4%	0	0

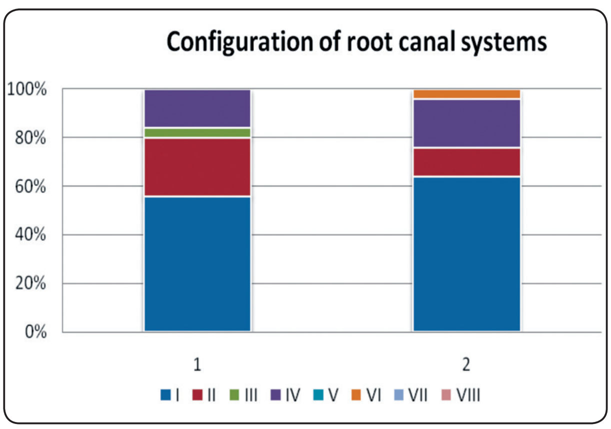

Fig. (4) Bar chart representing configuration of root canal systems in 1) maxillary permanent 1st molars and 2) maxillary permanent 2nd molars.

DISCUSSION

The purpose of this study was to determine the prevalence of MB2 in maxillary 1st and 2nd molars by using in vivo CBCT technique. In addition, we investigated the root canal system configuration in the MB root of maxillary 1st and 2nd molars according to Vertucci's canal classification. The data obtained from this study should provide theoretical and experimental evidence that will encourage clinicians to acquire a comprehensive knowledge of the anatomy of the permanent maxillary first and second molars, which may increase the success rate of root canal treatment of maxillary molars. The MB2 canal was selected as a model for this study because it is considered to be highly prevalent, yet can be elusive in many patients. Locating the MB2 canal is a challenge for the clinician in achieving successful treatment of maxillary molars. If the prevalence of the MB2 is high in a population, time should be devoted to its location and treatment.

The mesiobuccal root of the permanent maxillary first molar may have more than one or two canals; it may also branch out from various sides and have lateral ramifications. Clinically, different canal configurations might require varying root canal procedures to facilitate complete cleaning, disinfection, and canal obturation. The root canal system of the mesiobuccal root of the permanent maxillary first molar frequently has more than one canal. Clinicians need to be mindful of the possible presence of a second mesiobuccal canal, which should motivate change in the routine practice of clinical endodontic treatment. Vertucci analyzed the anatomy of the root canal and proposed a classification that encompassed eight different types [(2)].

Because the in vitro techniques evaluate only the extracted teeth, they are not masked by other structures and thus are more accurate to identify the number of roots and canals in a tooth. However, they are time consuming due to involvement of many procedures to prepare the teeth for examination. Because the roots and root canals of the teeth may be obscured by the surrounding structures when taking the radiographs, the images of teeth may not be sharp enough for examining the details of the root and root canal systems of the teeth [(1)].

In the recent years, CBCT scanners have been increasingly developed specifically for dental and maxillofacial imaging. Overall, there are studies favoring the use of CBCT over conventional periapical (PA) radiograph. A study by **Hassan et al 2009** [(12)] found that CBCT had a significantly higher accuracy than PA radiographs. **Kamburoglu et al 2010** [(13)] showed that high resolution CBCT technology had a higher receiver operating characteristic curves Az value than digital PA radiograph. The disadvantages of CBCT imaging are inadequate soft tissue view and artifacts. Inadequate soft tissue view may not be a problem in dentomaxillofacial imaging, because the teeth and bones are mineralized tissues [(11)].

Recently, CBCT was used as the major technique for studying the root and root canal systems of human teeth in vivo. The distinct advantage of CT is that it provides 3D information of the teeth and jaw bones and needs only a lower radiation dose to produce a high-quality image [(1)].

CBCT was used for the assessment of root canal configurations. Panoramic evaluation of root canal configurations can be misleading because of its two-dimensional nature. It has been reported that three-dimensional images identified a greater number of morphologic variations than panoramic radiographs. Thus, CBCT can be beneficial clinically for detecting complex root canal configurations [(14)].

Neelakantan et al 2010 [(15)] compared the accuracy of several techniques in studying the root and root canal morphology of extracted human teeth. When modified canal staining and clearing technique was used as the gold standard, they found that CBCT and peripheral quantitative CT are as accurate as the gold standard in identifying root canal systems. In addition, CBCT was shown to be more accurate than spiral CT and plain and contrast medium-enhanced digital radiography in studying the root canal morphology of teeth [(14, 16)].

Although CBCT scanning has advantages for root canal anatomy investigations, according to recommendations, the use of CBCT scanning depends on outweighing the benefits with the risks. The use of CBCT results in exposing the patient to ionizing radiation that may pose elevated risks to some patients (e.g., cases of pregnancy, previous treatment with ionizing radiation, and younger patients). Thus, CBCT should be reserved for selected cases when conventional imaging fails to provide defined information about complex endodontic conditions [(14)].

In the current study CBCT examination showed that out of 25 maxillary first permanent molar teeth studied, the mesiobuccal roots with a single canal were of type I (56%) (14 teeth) or type III (4%) (one tooth) configuration. Those with two canals were of type II (24%) (6 teeth) or type IV (16%) (4 teeth) configuration.

Regarding the maxillary second permanent molar teeth CBCT examination revealed that out of 25 maxillary second permanent molar teeth studied, the mesiobuccal roots of 16 teeth were with a single canal of type I (64%) configuration. Those with two canals were of type II (12%) (3 teeth), type IV (20%) (5 teeth) or type VI (4%) (one tooth) configuration.

Supporting our results **Peeters et al 2011** [2] reported that maxillary molars often have two canals in the mesiobuccal root. They found the frequency of teeth with two MB canals with separate foramina was 52.6%, whereas the percentage of joined foramina was 47.4%. However, an *in vitro* study by **Kullid and Peters 1990** [17] noted a very high prevalence of 95.2%. Limited access and visibility in clinical settings, as well as the risk of perforation, may explain the lower prevalence of MB2 canals as compared with *in vitro* studies. It is possible that the use of an operating microscope or loupes to enhance the view of the operative field might increase the ability to locate the MB2 canal.

Filho et al 2009 [18] investigated the internal morphology of maxillary first molar by three different methods: ex vivo, clinical, and cone beam computed tomography (CBCT) analysis. In all these different methods, the number of additional root canals and their locations, the number of foramina, and the frequency of canals that could or could not be negotiated were recorded. In the ex vivo study, 140 extracted maxillary first molars were evaluated. After canals were accessed and detected by using an operating microscope, the teeth with significant anatomic variances were cleared. In the CBCT analysis, 54 maxillary first molars were evaluated. The ex vivo assessment results showed a fourth canal frequency in 67.14% of the teeth, besides a tooth with 7 root canals (0.72%). Additional root canals were located in the mesiobuccal root in 92.85% of the teeth (17.35% could not be negotiated), and when they were present, 65.30% exhibited 1 foramen. Clinical assessment showed that 53.26%, 0.35%, and 0.35% of the teeth exhibited 4, 5, and 6 root canals, respectively. Additional root canals were located in this assessment in mesiobuccal root in 95.63% (27.50% could not be negotiated), and when they were present, 59.38% exhibited 1 foramen. CBCT results showed 2, 4, and 5 root canals in 1.85%, 37.05%, and 1.85% of the teeth, respectively. When present, additional canals showed 1 foramen in 90.90% of the teeth studied. The study demonstrated that operating microscope and CBCT have been important for locating and identifying root canals, and CBCT can be used as a good method for initial identification of maxillary first molar internal morphology.

Blattner et al 2010 [19] studied the efficacy of cone beam computed tomography (CBCT) as a modality to accurately identify the presence of second mesiobuccal canals (MB2) in the maxillary first and second molars, they collected twenty completely intact maxillary first and second molars and evaluated the existence of the MB2 using three different methods by: periapical radiographic evaluation, CBCT evaluation, and clinical sectioning evaluation. Radiographic evaluation revealed the presence or absence of two canals that was recorded by a consensus of the endodontist and radiologist for each of the 20 teeth. CBCT evaluation positively identified the MB2 canal in 57.9% of samples, whereas the clinical sectioning evaluation identified an MB2 canal in 68.4% of samples. Both of these percentages were somewhat lower than other literature has suggested for the prevalence of MB2 canals in these teeth, but the small sample size likely accounts for the discrepancy of more relevance in this study, however, was that a positive correlation between CBCT scans and clinical sectioning diagnoses was present in 79.0% of samples.

Kottoor et al 2010 [20] presented a case of maxillary first molar with unusual canal morphology, they evaluated the involved tooth using radiographic examination but it didn't indicate any variation in the canal anatomy, the amount of information gained from conventional radiographs and digitally captured periapical radiographs is limited by the fact that the three-dimensional anatomy of the area being radiographed is compressed into a two-dimensional image. CBCT scanning was used for a better understanding of the complex root canal anatomy. CBCT axial images confirmed the presence of three roots and seven root canals, namely mesiobuccal1 (MB1), mesiobuccal2 (MB2), mesiobuccal3 (MB3), distobuccal1 (DB1), distobuccal2 (DB2), mesiopalatal (MP) and distopalatal (DP). Contralateral tooth appeared to have normal root canal anatomy.

Inconsequence with our results **Neelakantan et al 2010** [15] studied the root and canal morphology of maxillary first and second molars in an Indian population by using CBCT. The number of root canals was examined, and root canal system configurations were classified by using historical and contemporary classifications. They found that Single rooted first and second molars commonly showed types I, IV (0.5%) and type III (1%) canal systems, respectively. Buccal roots of two-rooted first molars showed 2 canal systems, type I and type IV, whereas second molars with 2 roots showed wide variations in canal anatomy. The most common canal morphology in the mesiobuccal roots of three-rooted first and second molars was type I (51.8% and 62%, respectively), followed by type IV (38.6% and 50%, respectively).

Zhang et al 2010 [21] identified the morphology of maxillary permanent molar teeth in Chinese subpopulation, they used CBCT to evaluate the root and canal systems of maxillary first and second molars, The results revealed that all of the maxillary first molars had three roots. The majority (52%) of the maxillary first molars had four canals, and 48% had three. All the fourth canals of the maxillary first molars were in the MB roots. In maxillary second molars, 81% had three separate roots, 9% had two roots, and 10% had a single root. In addition, two variants in the root canal anatomy of maxillary first molars and eight variants in maxillary second molars were identified. This indicates that maxillary second molars have a more complex root canal system. The most common anatomy of the maxillary first molar is that categorized as Variant II, with one canal in each of the DB and P roots and two canals in the MB root. The most common anatomy of the maxillary second molar with three roots, categorized as variant I, has three separate canals. The complexity in the root canal morphology of maxillary molars mostly relates to the presence of the MB2 canal. MB2 canals were present in 52% maxillary first molars and 18% maxillary second molars. Clearly, the study demonstrates that CBCT is an effective and powerful technique for detection of MB2 canals.

Guo et al 2014 [22] reported that MB2 occurrence only showed statistically significant differences among age groups (P = .005). They investigated that in the mesiobuccal roots, the most common Vertucci classifications of canal types were type IV (41.9%), type I (28.3%), and type II (26.3%). Also **Shahi et al 2007** [9] found that out of 137 maxillary first permanent molar teeth studied, the mesiobuccal roots with a single canal were of type I (37.96%) or type V (9.5%) configuration. Those with two canals were of type II (24.08%), type IV (24.18%) or type VI (4.38%) configuration.

Against our results **Somma et al 2010** [7] investigated that a MB2 canal was present in 80% of the cases (24 teeth). It was a completely independent canal in 42% of specimens (10 teeth). In five teeth (21% of the cases in which the MB2 was present), the MB2 canal had its origin some distance down the orifice of the MB1 canal.

CONCLUSION

The root canal system of the mesiobuccal root of the permanent maxillary first and second molars frequently has more than one canal. As failure to detect an MB2 canal is one of the major factors that contribute to the high failure rate of root canal treatment clinicians need to be mindful of the possible presence of a second mesiobuccal canal, which should motivate change in the routine practice of clinical endodontic treatment.

CBCT scans certainly show promise as a modality to facilitate the identification of root and canal configuration. The information gained about the tooth anatomy and canal morphology before treatment could potentially facilitate root canal therapy.

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