CBVT analysis of canal configuration of the mesio-buccal root of maxillary first permanent molar teeth: An *in vitro* study

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Abstract

Context: For successful endodontic treatment, it's imperative to locate and obturate all root canals. As concluded by Ingle, the major cause for failure of root canal therapy is in ability to recognize all theexisting canals and subsequent failure in their obturation. **Aim:** To analyze the canal configuration of the mesio-buccal root of maxillary first permanent molar teeth. **Materials and Methods:** A total of 30 recently extracted human permanent maxillary first molars were collected and stored in a container with 5% Sodium Chloride solution for four days. Teeth with open apices, external resorption, improperly formed roots and teeth with previous restorations were excluded. Using the dental modeling wax, teeth were arranged in a 'U' shaped arch with roots embedded inside the wax and occlusal surface remaining free. 10 teeth were arranged in each arch and three such sample plates were prepared. Flat surface of the base encasing enabled the plate to be mounted on flat plastic bite plate. With bite plate roughly centered in the focal trough area Axial, Coronal and Sagittal section Cone-Beam Computed Tomography (CBCT) images were taken with Kodak 9000 Extra-oral Imaging System. Images displayed on a monitor were inspected by two endodontists using Kodak Dental Imaging Software 3D Module V2.2. **Statistical Analysis:** When the data was observed, it was found that 24 teeth out of total 30 teeth examined showed some variation (i.e. possible additional canal) along the length of the mesio-buccal root canal. Out of these 24 teeth, 13 showed presence of additional canal at coronal third, 7 showed presence of additional canal at middle third and four showed presence of additional canal in apical third level. Percentage analysis was done as there was no group comparison to be done. **Results:** Cone-Beam Volumetric Tomography (CBVT) evaluation positively identified the variations in mesio-buccal canal in 80% of samples. Out of these, 54.16% were in coronal 3rd, 29.16% in middle 3rd and 16.66% were in apical 3rd. **Conclusion:** Within the limitations of this study, it can be concluded that- (1) more than half of maxillary first molars have four canals and (2) most of the additional canals were located in the MBR and CBVT is a good diagnostic tool to help diagnose these additional canals. Further investigations using larger sample sizes would be helpful.

Keywords: Cone-beam computed tomography, cone beam projection geometry, MB2 canal, root canal system

Introduction

Successful endodontics depends upon identification, cleaning and completes obturation of the complicated root canal system. For this, the clinician should be thoroughly aware of root and its morphology. This will help him to locate all the canals, debride and seal them completely with a root canal filling.[1] However, root canal morphology varies in all individuals and no two canals are same.

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Maxillary first permanent molars are frequently affected by caries at an early age and may necessitate root canal treatment.

Visualization of root canal on X-rays has helped us to view root canal in individual tooth and plan the treatment accordingly. But, since it's a two dimensional picture, additional canals are often missed.

Morphology of Maxillary first permanent molars has been studied extensively for its complexity in canal configuration.[2,3] It is well accepted that mesial root of Maxillary first permanent molar contains more than one canal. Revealing the location of this second mesio-buccal canal has proven to be the most formidable component of adequately treating these canals. Wolcott et concluded that failure to find and treat the existing 2nd canal decreases the long term prognosis.[4] Factors such as ethnic background,[5] age[6,7] and gender[1,2] may also play a role in imparting variations in canal morphology.

Various methods have been used to identify this 2nd canal. These include clearing technique combined with dye penetration,[8,9] Cross section analysis, Conventional radiographic examination,[10] macroscopic examination[11] and magnification[12] with operating microscope.[6,12-14]

Limitations of conventional radiographic technique have led to introduction of advanced modalities such as Spiral Computed Tomography (SCT) and Cone-Beam Computed Tomography (CBCT).

CBCT was introduced in the field of endodontics in 1990's.[15] CBCT system was developed for pre-surgical implant planning, TMJ examination, large cysts and tumors and Facial trauma cases. The endodontic applications are 3D information of the teeth and surrounding tissues, identification of variations in root canal system, assessment of endodontic/non-endodontic pathosis and for internal and external resorption analysis.[16]

Therefore, considering the limitations of conventional techniques for locating the 2nd mesio-buccal canal, advanced imaging technique such as CBCT was used in the current study. The purpose of the study was to analyse canal configuration of the mesio-buccal root of maxillary first permanent molar teeth with an objective to detect the prevalence of 2nd mesio-buccal canal in mesial root.

Materials and Methods

A total of 30 recently extracted human permanent maxillary first molars were collected and stored as per CDC guidelines.

Exclusion criteria

- Teeth with open apices,
- External resorption,
- Improperly formed roots,
- Aberrant anatomy,
- Teeth with previous restorations

Teeth were cleaned of any adherent soft tissue, bone fragment and calculus by scaling and polishing. These teeth were placed in a container with 5% Sodium Chloride solution which was changed daily for four days.[16]

A "U" shaped template mimicking the natural arch form was made with modeling wax. 10 teeth were embedded in each arch with the roots inside the wax and occlusal surface exposed. Three such samples were prepared to be mounted on extra-oral imaging system [Figure 1].

The base of the wax encasing was formed into a flat surface enabling the plate to sit stationary on top of the flat plastic bite plate. Roughly centered in the focal trough area, a preview picture was taken.

The prepared sample plates were then placed onto the bite-plate of Kodak 9000 Extra-Oral Imaging System [Figure 2]. To confirm the internal anatomy, Axial, Coronal and Sagittal section CBCT images were taken with Kodak 9000 Extra-oral Imaging System with tube voltage of 70 KV and tube current of 10 mA.

Images displayed on a monitor were inspected by two endodontists using Kodak Dental Imaging Software 3D Module V2.2.

Various criteria have been proposed to consider the canal as a 2nd mesio-buccal canal.[14,13] To be included and recorded as a 2nd mesio-buccal canal, the canal has to be traced till a depth of 4-5 mm from the Cemento-Enamel junction.[1] Presence of additional canal beyond this depth was considered as an anatomic variation and not as a 2nd mesio-buccal canal.

Discussion

It is generally accepted that a major cause for failure of root canal therapy is an inability to recognize the presence of and to adequately treat all of the canals of the root canal system. Weine *et al,* were one of the first to acknowledge that the failure of endodontic treatment of maxillary molars is likely due to the failure to locate and fill the MB2 canal.

The incidence of additional canal in mesio-buccal root

Figure 1: Arrangement of extracted teeth in modeling wax to be mounted on Kodak 9000 extraoral imaging system

varies with the method used in the study. Clinical studies (Neaverth *et al.*1987, Fogel *et al.*1994, Stropko 1999, Buhrley *et al.* 2002, Wolcott *et al.*2002) have reported their prevalence to be in the range of 18.6-80.3%. In laboratory studies using clearing techniques (Pecora *et al.*1991, Al Shalabi *et al.* 2004, Gulabivala *et al.*2001) reported a range of 25-93.5%. Pomeranz and Fishelberg (20) demonstrated a great discrepancy exists between clinical and *in-vitro* laboratory studies in the incidence of MB2 canals. The *in-vitro* studies suggested the incidence of MB2 canals to be extremely high than the clinical studies, but they do not necessarily relate to the routine, daily observations in clinical practice. Considering the same reason, the study was planned to include CBVT as a diagnostic method which can help us to identify the presence of additional canals before proceeding for the treatment.

Weine also suggested that the mesio-buccal root of the Maxillary first molar contains a double root canal system more often than a single canal. Especially, if radiograph indicates possibility of second canal in MBR and root is shorter than average, then it should attempted with vigor until the canal is located.

Conventional radiographic examination, though an essential pre-requisite for managing the endodontic problems,[17] has its own limitations. The three-dimensional information is compressed into two-dimensionl anatomical image form.[18] The interpretation becomes difficult when the background pattern is complex (e.g. posterior maxillary region).[19] Actual extent of lesions and their relation to other structures in the direction of the X-ray beam is not shown. Other disadvantages include relatively higher radiation dose exposure, image distortion, processing errors and time consumption.

Newer diagnostic modality, spiral computed tomography (SCT) acquires raw projection data with a spiral sampling locus. Multi-planar reconstruction helps to reconstruct overlapping structures and achieves higher resolution of smaller objects. But it's still not very much accurate and it does not limit the dosage as low as reasonably achievable.

CBCT uses a cone shaped beam of radiation to acquire data in a single 360° rotation.[20] This reveals the internal architecture of an object. One of the advantages of CBCT over conventional CT scanning is X-ray beam limitation (collimation of primary beam) and significant dose reduction (Conventional CT-100-300 μSv for maxilla and 200-500 μSv for mandible. CBCT-34-102 μSvfor both maxilla and mandible).[21,22] Additional use of thyroid collar and patient positioning modifications can reduce dosages by up to 40%. Rapid scan time (10-70 sec) makes it comfortable for patient.

To detect this second canal, we mounted the extracted teeth into the modeling wax to form a "U" shaped arch which will simulate the arch form and also help to properly place this sample onto the Extra-oral imaging system. The teeth were mounted with roots vertically embedded into the modeling wax and occlusal surface kept free.

During analyze of the obtained images using Kodak Dental Imaging Software 3D Module V2.2 [Figure 3], while moving from occlusal surface towards the apical surface, presence of additional canal was confirmed only when the particular canal could be traced till a depth of 4-5 mm from the Cemento-Enamel junction. Any additional canal beyond this depth was considered as an anatomic variation and not as a 2nd mesio-buccal canal.

On data analysis, it was found that 24 teeth out of total 30 teeth examined showed some variation (i.e. possible additional canal) along the length of the mesio-buccal root canal [Table 1]. Out of these 24 teeth, 13 showed presence of additional canal at coronal third, seven at middle third and four at apical third level [Table 2]. As per the criteria decided, additional canal present at coronal level, which

Figure 2: Kodak 9000 extraoral imaging system

Figure 3: CBVT image indicating presence of 2nd canal in mesio-buccal root

Table 1: Anatomic variation in canals in MBR

Tooth no.	2nd canal found at the level from CEJ (mm)
1	13.69
2	No
3	17.44
4	13.31
5	No
6	11.17
7	15.53
8	No
9	14.15
10	17.44
11	13.85
12	11.78
13	12.09
14	No
15	14.92
16	16.75
17	12.01
18	17.06
19	14.46
20	16.52
21	16.22
22	16.83
23	16.83
24	16.83
25	12.93
26	No
27	12.70
28	11.70
29	15.93
30	No

Table 2: Second mesio-buccal canal in MBR

Tooth no.	From CEJ (mm)
1	4.59
2	No
3	11.25
4	5.28
5	No
6	5.05
7	10.02
8	No
9	5.43
10	4.44
11	3.98
12	3.45
13	6.20
14	No
15	5.74
16	6.89
17	11.66
18	4.97
19	4.90
20	4.44
21	6.22
22	6.51
23	4.05
24	4.44
25	4.21
26	No
27	2.14
28	4.06
29	10.18
30	No

could be traced at least halfway to the apex, was considered as a second mesio-buccal canal.

Conveniently, the additional canal in mesio-buccal root is called as MB2. But MB-2 is a poor and inappropriate terminology and has no parallel in endodontic practice. So, it's appropriate to term it as Second mesio-buccal canal.

Broad bucco-lingual dimensions of the mesial root and associated cavities on its mesial and distal surfaces is consistent with the existence of two canals in mesio-buccal root.[2]

But at the same time, "cone beam" projection geometry is responsible for image "noise" which reduces image clarity and limits adequate visualization of dento-alveolar structures. Other limitations include detector sensitivity, and contrast resolution.

The incidence of second mesio-buccal canal has been reported to be between 18%[16] and 96.1%[12] (Commonest variation). In the current study, CBCT evaluation positively identified the variations in mesio-buccal canal in 80% of samples [Figure 4]. Out of these, 54.16% were in coronal 3rd, 29.16% in middle 3rd and 16.66% were in apical 3rd [Figure 5].

Conclusion

Although not yet at 100% accuracy, CBVT method certainly show promise as a modality to be added in endodontic practice, particularly in situations in which the MB2 canal was not detected and treated.

Within the limitations of this study, it can be concluded that-

1. more than half of maxillary first molars have four canals and

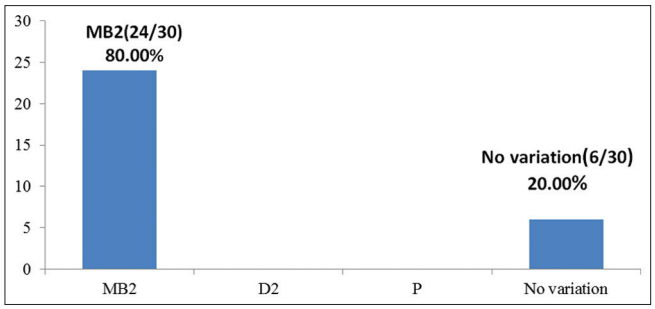

Figure 4: Anatomic variation in canals in MBR

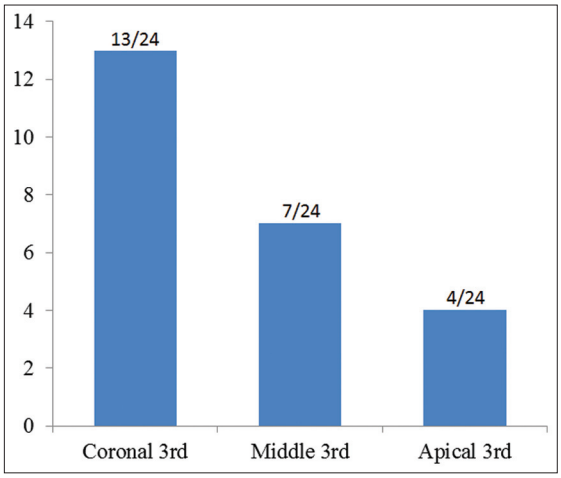

Figure 5: Second mesio-buccal canal in MBR

2. most of the additional canals were located in the MBR and CBVT is a good diagnostic tool to help diagnose these additional canals

Further investigations using larger sample sizes would be helpful.

These scans may help the clinician to locate additional canals in the maxillary first molar and thereby achieve better outcomes for the endodontic treatment of these teeth.

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