The prevalence of second canals in the mesiobuccal root of maxillary molars: A cone beam computed tomography study

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Prevalence of MB2 canals as detected by CBCT.

Keywords: CBCT, endodontic treatment, MB2, root canal anatomy

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Abstract

The aim of this study was to determine the prevalence of MB2 canals in permanent maxillary molars utilising CBCT; in patients attending a university hospital. A total of 200 patient scans, (100 female and 100 male patients), were enrolled in the study. In total, 800 teeth were analysed, and teeth with additional canals in their MB roots (MB2) were identified. First maxillary molar teeth exhibited the highest prevalence of MB2 canals, 92% and 87%, for teeth 16 and 26 respectively. Second maxillary molar teeth showed a lower prevalence of MB2 canals, 69% and 65%, for the 17 and 27 respectively. There were no associations of significance between the prevalence of MB2 canals and patient age or gender. Root morphology and anatomy of permanent maxillary first and second molar teeth was found to be highly variable. The prevalence of additional canals in the MB roots is a frequent finding which has previously been underreported.

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Introduction

Endodontic therapy is routinely carried out for the treatment of irreversible pulp and periapical disease in order to retain the natural dentition. Endodontic success is reliant on the complete disinfection, debridement; and obturation of the root canal system, and therefore an intricate knowledge of canal anatomy is a pre-requisite for accurate treatment (1-4). Despite advances in implant technology, many patients regard retention of their natural dentition as preferable.

Though endodontic therapy remains a viable and successful treatment option, maxillary permanent molar teeth have amongst the highest endodontic failure rates of all teeth, owing to the complexity of their root canal anatomy, and variations found in the morphology of their mesiobuccal (MB) roots (2, 5-7). This root has been extensively researched (8), and while most studies indicate the presence of a second MB canal (MB2), consensus is still lacking regarding its prevalence (2, 3, 9-12). An inability to locate and adequately treat all canals of a root canal system during endodontic treatment; often leads to persistence of residual bacteria, thereby causing recurrent infection, periapical inflammation and ultimate treatment failure (13).

The previously reported variation in MB2 prevalence has been attributed, in part, to the diverse and disparate methods used to identify these canals. Methods used previously for the recognition of MB2 canals include radiography, tooth sectioning with dye staining, and magnification using dental loupes and operating microscopes (8, 14, 15). Studies have shown that MB2 detection rates vary considerably, with resultant failure to identify these clinically (2, 14, 16, 17). In addition, the high incidence of locating these canals during endodontic retreatment cases, followed by uneventful healing, suggests that endodontic failure rates may correlate with the inability to detect additional canals at treatment onset (13, 14).

Tooth root morphology is usually assessed on pre-operative periapical (PA) radiographs. These images are inadequate for assessing the presence of extra canals, such as MB2, as they are a two-dimensional (2D) representation of a three-dimensional (3D) entity, subject to distortion by surrounding structures. New imaging technologies allows for greater and more precise anatomic distinction. Cone beam computed tomography (CBCT) is a non-invasive, non-destructive, economically viable technique to reliably identify MB2 canals clinically at the diagnostic, pre-treatment stage, and has been previously reported (7, 18-20). A number of studies have examined the prevalence of MB2 canals by CBCT alone (3, 6, 7, 12, 19, 21-

24). The discrepancies in prevalence between reported studies are related to differences in methodology, age, geographical location, and CBCT systems. These results may be compared with those from previous studies for enhanced anatomical knowledge and greater therapeutic success. The aim of this study was to determine the prevalence of MB2 canals in permanent maxillary molar teeth by accessing the CBCT database at the Oral and Dental Hospital of the University of Pretoria, South Africa.

Materials and methods

Patient assessment

This is a retrospective cross-sectional study utilising 200 CBCT scans, taken over a three-year period, to determine the prevalence of MB2 canals in permanent maxillary molar teeth in patients attending a university institution. 1210 CBCT scans (from 1 January 2014 to 31 December 2016) were examined for inclusion criteria. Two hundred consecutive cases, representing one hundred female and one hundred male patients, which met the criteria, were included in the study. The average patient age was 37 years (ranging from 18 to 72 years). Ethics approval was obtained by the Faculty of Health Sciences Research Ethics Committee of the University of Pretoria, South Africa, and the sample size of 200 patients was found to be adequate to estimate prevalence to an accuracy within 10% (0.1).

The inclusion and exclusion criteria were defined as follows:

Inclusion criteria:

1. Patients above the age of 18 years with healthy maxillary permanent first and second molar teeth on both sides.

Exclusion criteria:

1. Teeth with open apices, fractures, periapical lesions, resorption, or calcifications.

2. Developmental anomalies.

Radiographic analysis

Two hundred patients, scanned with the Planmeca ProMax 3D Max X-ray unit (Planmeca Oy, Helsinki, Finland), were studied using the manufacturer's software (Planmeca Romexis). Resolution for this unit was established via voxel sizes ranging from 100µm to 600µm with 300-750 basic frames. The focal spot size was 0.6x0.6mm. The anode voltage was 54 – 90 kV and the anode current was 1-14 mA. All CBCT examinations were carried out by an experienced radiographer. MB2 canals were identified by a resident post-graduate student in Prosthodontics, the speciality which incorporates Endodontics in South Africa, whose training also includes a Radiology component with particular emphasis on advanced 3D imaging such as CBCT. Canal identification was achieved using sequential axial, coronal, and sagittal CBCT slices by careful scrolling through the maxillary permanent molar teeth, from the pulp chamber to the apex. The maximum voxel size for each scan was 200µm, the width of the periodontal ligament space. Optimal visualisation was achieved by adjusting the brightness and contrast of the chosen image as required, with the systems software tools.

Thirty randomly chosen cases, representing 120 teeth, were assessed and examined by a second observer, a prosthodontist with over 20-years' clinical experience in endodontics. This was done to establish inter-observer agreement and reliability of the data.

Data analysis

Data was initially captured using Excel 2003 (Microsoft Office Excel 2003, Microsoft). Statistical analysis was performed by means of SPSS 23.0 software (IBM SPSS Statistics v23.0; IBM Corp, 2015). Prevalence of MB2 canals in permanent maxillary molars was recorded as a percentage along with a 95% confidence interval. The Pearson's chi-squared test was used to determine the association between MB2 and demographic variables (age, gender, tooth position). The participants were specified as the random component, while age, gender, and tooth position were fixed.

Cohen's kappa coefficient was employed to measure inter-observer reliability. Values < 0.2 are regarded as none to slight agreement, 0.21 - 0.4 as fair agreement, 0.41 - 0.6 as moderate agreement, 0.61 – 0.8 as substantial agreement, and 0.81 – 1.0 as almost perfect agreement.(25) For medical and scientific research validity, inter-observer reliability should be above 0.6 (25).

Among patients with MB2 canals, the probability of contralateral and adjacent occurrence, was calculated for each tooth position. The ability of a prevalent MB2 canal to predict a MB2 canal in the contralateral and/or adjacent molar tooth was measured by determining the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), false-positive and false-negative values for each comparison. For statistical significance, testing was done at the 0.05 level of significance ($p < 0.05$).

Results

The prevalence of detecting an MB2 canal was as follows: 92% for permanent first maxillary molar teeth in the first quadrant (16), 87% for permanent first maxillary molar teeth in the second quadrant (26), 69% for permanent second maxillary molar teeth in the first quadrant (17), and 65% for permanent second maxillary molar teeth in the second quadrant (27). Inter-observer agreement for the measurements were 0.78, 1.00, 0.82, and 0.57 for teeth 16, 26, 17, and 27 respectively, as measured by Cohen's kappa.

The prevalence of MB2 canals was also calculated according to patient gender (Table 1), and age for each tooth (Table 2). The Pearson’s chi-square test did not show a significant association between patient gender and the presence of MB2 canals, as well as between patient age and the presence of MB2 canals, for both first and second maxillary permanent molar teeth.

Table 1: Prevalence of MB2 canals in the first and second permanent maxillary molars according to gender

		Tooth 16	Tooth 26	Tooth 17	Tooth 27
Gender	n	%	%	%	%
Female	100	91	84	66	64
Male	100	93	90	72	66

Table 2: Prevalence of MB2 canals in the first and second permanent maxillary molars according to age

		Tooth 16	Tooth 26	Tooth 17	Tooth 27
Age (y)	n	%	%	%	%
18-30	79	92.4	86.1	69.6	65.8
31-50	85	91.8	88.2	69.4	64.7
>50	36	91.7	86.1	66.7	63.9

Among patients with MB2 canals, the probability of contralateral and adjacent occurrence, was calculated for each tooth position. Contralateral occurrence of MB2 canals was found to be 97.13% for the permanent first maxillary molars (16,26), and 88.46% for the permanent second maxillary molars (17,27). Adjacent occurrence was similar for both sides, 94.52% in the first quadrant (16,17), and 94.62% in the second quadrant (26,27).

Table 3: Probability accuracy assessment of MB2 canals in different tooth positions

Test measurement	Probability of an MB2 canal in the contralateral tooth		Probability of an MB2 canal in the adjacent tooth	
	16*/26	17*/27	16*/17	26*/27
Sensitivity (%)	92	83	72	71
Specificity (%)	69	76	50	73
PPV (%)	97	88	95	95
NPV (%)	42	67	13	27
False-positive result (%)	3	8	4	4
False-negative result (%)	8	12	26	26

* Demarcates the reference tooth used in the calculation

The validity of a present MB2 canal to predict a MB2 canal on the contralateral side is presented in Table 3. With a sensitivity of 92%, a PPV of 97%, and the least false-positive and false-negative results, the likelihood of contralateral occurrence of MB2 canals in permanent first maxillary molar teeth (16,26), was considerably better than for other tooth positions.

Discussion

A multitude of methods have been employed and documented for the determination of MB2 presence, both *in-vitro* and *in-vivo*. *In-vitro* studies require extraction of teeth often followed by destruction through sectioning, tooth clearing and root canal staining, and micro-computed tomography (MCT) analysis. These methods have formed the main reference standards in the determination of the presence or absence of MB2 canals (26-29). Results from these *in-vitro* studies have revealed an MB2 prevalence of between 90% (MCT) and 93.5% (tooth clearing and root canal staining) (8, 30). These results compare favourably with ours (87-92%), which validates the findings in the present study and confirms that CBCT examination of teeth may be used for the detection of additional canals.

Other methods of determining the prevalence of MB2 canals include the use of advanced imaging techniques, such as medical CT and CBCT. Studies have shown results from these studies to be comparable with those of tooth sectioning and MCT, the gold-standards for detecting MB2 canals, in terms of accuracy (7, 22). As CBCT has become more widely available, is more economical, and produces images at significantly lower levels of ionising radiation (compared to medical CT), it has become the method of choice for locating MB2 canals.

There have been numerous CBCT studies investigating root canal morphology (1, 6, 7, 12, 21-23, 31). Regarding the prevalence of MB2 canals in maxillary molars, our results (87-

92%) are similar to another study (86-91%) (23). In that study, 100 male and female patients with healthy, untreated, and fully developed maxillary molars were assessed for the presence of MB2 canals. Criteria (inclusion and exclusion) were similar for both studies, as was the voxel size (200µm) for obtaining the CBCT images. This may explain the similarities in results.

Other CBCT studies, however, have shown significantly lower levels of MB2 canal prevalence. One study which evaluated root canal configuration of maxillary molars by CBCT, reported a low incidence of MB2 detection (34-42%) (3). Though these scans were obtained at similar voxel sizes of 200µm to our study, and the sample size was similar, the difference in results could be explained in terms of manufacturer software. Images from this study were obtained between 2010-2012, whereas our study's images were obtained from 2014-2016. Constant software developments and improvements of CBCT systems have greatly enhanced the resolution of images, especially when viewed (assessed) on a computer screen. Another possible explanation for the different results could be ethnic diversities, however, the comparative study mentioned in the previous paragraph, and the one mentioned here, were both carried out in the same country. Thus, ethnicity cannot be regarded as a possible reason for these differences.

CBCT parameter settings and software differences could also be the reason for the reduced MB2 prevalence rates seen in other studies, such as 52% seen in a Chinese study carried out in 2009 (21), 64% in a Korean study carried out in 2011 (6), and 66% in a North American study carried out between 2007-2012 (12).

Our results did not show a significant association between patient gender and MB2 prevalence. This is similar to two other studies in the literature (12, 23). A significant association between patient gender and MB2 prevalence have, however, been documented previously (6, 30).

MB2 prevalence is reduced with increasing age, showing a statistically significant association (6, 12, 21, 23, 24, 30, 31). This is to be expected, as dental structural changes occur with aging. The most significant of these is the continued deposition of secondary dentine, leading to dentinal sclerosis and pulpal recession (32, 33). Thus, canals become obliterated as there is a reduction in pulpal volume, making it difficult to locate the MB2 canal, if it is at all present. Our study, however, had fewer patients over the age of 50, with the oldest patient in our sample being 72-years old. Though, our results showed MB2 canals to be equally prevalent across all age groups, which is unexpected, this has also been documented in the study performed by Kim et al., whose oldest patient was 69-years old. Clinicians should therefore be made aware that MB2 canals can present at any age.

Adjacent and contralateral occurrence of MB2 canals has only been reported in one other study (6). Our results of bilateral symmetrical occurrence of 97% and 88% for the maxillary first and second molars respectively, are significantly higher than that obtained in that study, which showed an occurrence of 88% and 82% for the same tooth positions respectively. Probability of adjacent occurrence, that is between molar teeth on the same side, was also significantly higher in our study (95%), when compared to the study by Kim et al. (64%). Though the sample size of the study by Kim et al. (n=351) was significantly higher than ours (n=200), their study occurred five years before ours. Continuous software improvements by CBCT manufacturers have allowed for improvements in image resolution, leading to greater diagnostic accuracy and precision.

Documentation reaffirms that a greater prevalence of MB2 canals is present in patients than is known or conventionally taught. Of primary significance, should be the emphasis on the importance of being clinically aware of the presence of such canals, which may allow for better (improved) endodontic therapy, as well as allocation of sufficient treatment time. The overall outcome would thus be an improvement of endodontic success in the treatment of these teeth.

Conclusion

In the present *in-vivo* CBCT study, it was shown that the prevalence of MB2 canals in permanent maxillary molar teeth is very high, up to 92% in the first molar teeth. The likelihood of these canals being present in contralateral and adjacent molar teeth was also found to be high. Though endodontic therapy remains a viable treatment option for most teeth with high levels of success, the reasons for treatment failure in maxillary molar teeth may in part be attributed to a lack of knowledge regarding the prevalence of these canals, and difficulty in locating them intra-operatively. Untreated MB2 canals remain a source of persistent microbial infection and contamination contributing to endodontic treatment failure.

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