Original Article

DOI: 10.17354/ijss/2016/138

Internal Root Morphology of Maxillary First and Second Molars of South Indian Population by Canal Staining and Clearing Technique

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Abstract

Background: The success of endodontic treatment relies on the precise identification of all root canals followed by cleaning, shaping, and obturation. Maxillary molars present wide variations with regard to the number and type of root canals. The complexity of the root canals varies widely in different ethnic groups.

Aim of the Study: To investigate the root canal anatomy of permanent maxillary first and second molars in South Indian population.

Materials and Methods: Extracted 200 maxillary molars, maxillary first molars (100), and maxillary second molars (100) were collected from the section of South Indian population. Standard access cavities were prepared, and the teeth were immersed in 3% NaOCl to dissolve pulp tissue. Canal staining and clearing technique were used to study the root canal configurations of all the teeth.

Results: All maxillary first molars had three separate roots, whereas in second molars 41% were single rooted, 42 % two roots fused, and 16% three roots fused. The prevalence of second mesiobuccal canal (MB2) in maxillary first molars (84%) was higher than in second molars (38%). In the two-canalled MB roots, the Type II, IV, and VI canal systems were the most prevalent. Lateral canals in the apical third of the first molar were 51, 21, and 14% in MB, DB, and P, respectively; and in the second molar were 40, 15, and 5% in MB, DB, and P, respectively. Intercommunications in maxillary first molar were 32% and 4% in MB and DB, respectively. Palatal root curvature at apical third in first molar was buccal 70%, palatal 4%, and straight 20%.

Conclusion: In South Indian population, the prevalence of MB2 canal is more than 80% in maxillary first molars. The presence of lateral canals and intercommunications is also more in first molars. Full understanding of the potential complexities of the root canal system is essential for the successful endodontic treatment of maxillary molars.

Key words: Anatomy, Clearing, India ink, Maxilla, Molars, Root canal, South Indians

INTRODUCTION

Studying the root canal anatomy has both endodontic and anthropological significance. It is important to know the anatomy of teeth and its variations in different ethnic groups as such knowledge can aid in the identification, cleaning, and shaping of root canals. The presence of undetected canals, ramifications, and radiographically undetected curvatures have been attributed as possible causes for failure of endodontic treatment in maxillary molars.[1] A variety of techniques have been utilized to study the anatomical details of the root canal system. These techniques include microscopic studies, radiographic studies, sectioning of teeth, iontophoresis, injections, metal filling of pulp cavities, plastic embeddings, transparency/clearing, and combined techniques.[2] Even though there are discrepancies between *in vitro* and *in vivo* studies of root canal morphology, the technique of clearing teeth has considerable value because it makes the external surface

Access this article online

www.ijss-sn.com

Month of Submission : 01-2015
Month of Peer Review : 02-2016
Month of Acceptance : 02-2016
Month of Publishing : 03-2016

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transparent and helps in three-dimensional visualization of the pulp chamber and root canals.[3]

The pulp chamber and the root canals take on numerous configurations and shapes. The most frequent of the root canal ramifications are the apical delta, the accessory, and lateral canals.[2] An in-depth understanding of the complexity of the root canals and adequate cleaning, shaping, and filling of all the minute intricacies of the root canal system is essential for the successful outcome of endodontic treatment.[4] Maxillary first and second molars have fascinated researchers and clinicians due to their anatomical variations.[5] Because of the overall similarity of the first molar to the second molar, there may be a tendency for the clinician to treat them alike. In this study, both the teeth were analyzed as to the number of roots, canals, curvature, ramifications of the main root canal, localization and number of foramina, and apical deltas.

MATERIALS AND METHODS

The sample comprised 200 teeth (100 maxillary first molars and 100 maxillary second molars) collected all over from South India. The gender and age of the patients were not known. The teeth were extracted for reasons other than for this study. Teeth were stored in 10% formalin at room temperature during the period of collection. Hard and soft deposits were removed using ultrasonic scaler and washed under tap water. Once the teeth were classified into first and second molars, standard access cavities were prepared using Endo access burs and high-speed handpiece. Canal orifices were located by placing a size 8 K file into the visible orifice. The tooth was discarded if penetration was not possible into at least one canal orifice in the MB root.

The teeth were then placed in 5% sodium hypochlorite solution for 24 h to dissolve the organic tissue from the root surface and the root canal system. The teeth were dried, and Indian ink was injected into the pulp chamber using a hypodermic syringe with a 23-gauge needle and drawn through the canals using suction from apically. After 7 h of drying, the samples were stored in 5% nitric acid for 5 days to aid in the demineralization process. The fresh nitric acid solution was replaced daily and at the end of 5 days, the reliability of the demineralization procedure was verified by inserting a needle in the crown portion of the tooth. Decalcification of teeth was also confirmed by radiographs, which revealed complete radiolucency. Decalcified teeth were washed in running tap water for 4 h and dehydrated in ascending concentrations (70%, 95%, and 100%) of ethanol for 1 day and then rendered transparent by immersing in methyl salicylate for 2 days.

The transparent teeth samples were evaluated using a stereomicroscope at a magnification of 8×. The following observations were made: (1) Number of roots and their morphology; (2) number of root canals per root; (3) root canal configuration in each root using Vertucci's classification with additional modifications; and (4) presence and location of lateral canals and intercanal communications. Lateral canals were defined as those branches of main canals which diverged at right or oblique angles to exit onto the lateral surface of the root. Intercanal communications were denned as those complex canal ramifications that ran from and in between the main canals but did not communicate with the root surface (Figures 1-3).

RESULTS

All maxillary first molars had three separate roots, whereas in second molars 41% were single rooted, 42% two root

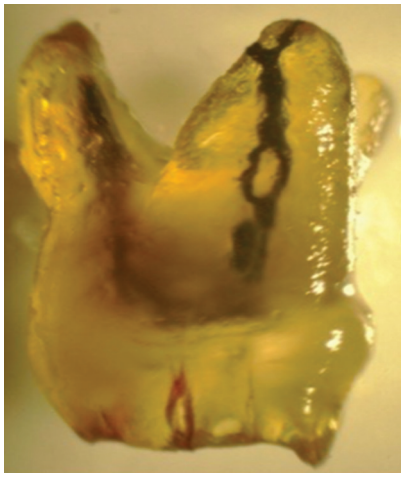

Figure 1: Cleared maxillary first molar showing Vertucci's Type VII root canal system

Figure 2: Cleared maxillary second molar showing accessory canals and ramifications

fused, and 16% three roots fused. The prevalence of second MB canal (MB2) in maxillary first molars (84%) was higher than in second molars (38%).

Tables 1 and 2 show the root canal configuration in maxillary first molars and maxillary second molars, respectively. In maxillary first molars, Type I canal systems were found to be 9%, 85%, and 96% in MB, DB, and P roots, respectively. Type II canal system was found to be 37% and 6% in MB and DB roots, respectively. Type III canal system was found to be 2% in MB root. Type IV canal system was found 20% in MB root. 5%, 7%, and 4% of Type V canal system was found in MB, DB, and P roots, respectively. Type VI was found to be 18% in MB, 2% in DB and Type VII 2% in MB. Additional canal system type (2-1-2-1) of 3% and type (2-3) of 4% were found in MB roots of first molars (Table 1). In maxillary second molars, Type I canal system was found to be 46%, 92%, and 95% in MB, DB, and P roots, respectively. Type II canal system of 18% was found only in MB. Type IV canal system was found to be 5% in MB root. Type V canal system of 17%, 8%, and 5% found in MB, DB, and P, respectively. 10% of Type VI was found in MB. Additional canal system type (2-3) of 4% found in MB root only (Table 2).

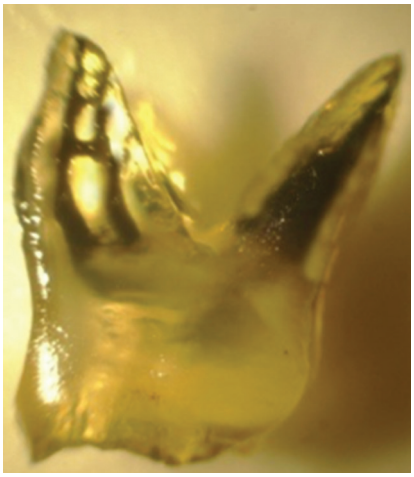

Figure 3: Cleared maxillary first molar showing intercommunications between canals

Table 3 shows the percentage of lateral canals in first molar MB, DB, and P roots in apical third to be 51%, 21%, and 14%, respectively. MB, DB, and P showed lateral canals in middle third to be 6%, 3%, and 2%, respectively. Lateral canals in coronal third of MB root were 2%. Lateral canals in second molar MB, DB, and P roots in apical third was 40%, 15%, and 5%, respectively, and 24%, 11%, and 72% in a middle third of MB, DB, and P, respectively. In the coronal third of MB, DB, and P roots, lateral canals were found to be 8%, 1%, and 1%, respectively.

Table 4 shows intercanal communications in MB and DB roots of maxillary first molars to be 32% and 4%, respectively. In the second molar, 6% of intercommunications were seen infused MB and DB roots, 5% in MB and P fused roots, and 3% in three roots fused.

Palatal root curvature at apical third in first molars was 70% buccal curvature, 4% had palatal curvature, and 20% of palatal roots were found to be straight. In second molars, the palatal root curvature was buccally (78%), distally (4%), and straight (15%) (Table 5). The buccal curvature of palatal roots was found to be less in first molars (average of 10°in 52%) compared to second molars (average of 20° in 45%) (Table 6).

DISCUSSION

It is extremely important for clinicians to be aware of the complexity of the root canal system that we are

Table 1: Percentage of maxillary first molars with different types of root canal configuration

Root (%)	Number of teeth	Type I (1)	Type II (2-1)	Type III (1-2-1)	Type IV (2)	Type V (1-2)	Type VI (2-1-2)	Type VII (1-2-1-2)	Type VIII (3)	Additional canal type	
										(2-1-2-1)	(2-3)
MB root	100	9	37	2	20	5	18	2	-	3	4
DB root	100	85	6	-	-	7	2	-	-	-	-
Palatal root	100	96	-	-	-	4	-	-	-	-	-

MB: Mesiobuccal, DB: Distobuccal

Table 2: Percentage of maxillary second molars with different types of root canal configuration

Root (%)	Number of teeth	Type I (1)	Type II (2-1)	Type III (1-2-1)	Type IV (2)	Type V (1-2)	Type VI (2-1-2)	Type VII (1-2-1-2)	Type VIII (3)	Additional canal type
										(2-3)
MB root	100	46	18	-	5	17	10	-	-	4
DB root	100	92	-	-	-	8	-	-	-	-
Palatal root	100	95	-	-	-	5	-	-	-	-

MB: Mesiobuccal, DB: Distobuccal

Table 3: Percentage of maxillary molar roots with lateral canals

Roots	Lateral canals (%)		
	Coronal third	Middle third	Apical third
First molar			
MB (100)	2	6	51
DB (100)	-	3	21
P (100)	-	2	14
Second molar			
MB (100)	8	24	40
DB (100)	1	11	15
P (100)	1	7	5

MB: Mesiobuccal, DB: Distobuccal, P: Palatal

Table 4: Number and percentage of maxillary molar roots with intercanal communications

Teeth	Group	Intercommunications (%)
Maxillary first molars	Group I	
	MB Root	32 (32)
	DB Root	4 (4)
	P Root	-
Maxillary second molars	Group II	
	MB+DB Root	6 (6)
	Group III	
	MB+P Root	5 (5)
	Group IV	
	3 roots fused	3 (3)

MB: Mesiobuccal, DB: Distobuccal, P: Palatal

Table 5: Palatal root curvature at apical third

Tooth	Buccal (%)	Palatal (%)	Mesial (%)	Distal (%)	Straight (%)
Maxillary first molars	70 (70)	4 (4)	3 (3)	3 (3)	20 (20)
Maxillary second molars	78 (78)	2 (2)	1 (1)	4 (4)	15 (15)

Table 6: Degree of curvature of palatal root at apical third

Tooth (%)	Buccal curvature in degrees				
	10°	20°	30°	40°	50°
Maxillary first molars	52 (52)	18 (18)	-	-	-
Maxillary second molars	27 (27)	45 (45)	6 (6)	-	-

expected to access, shape, clean, and fill.[4] Although various techniques have been used in studying the canal morphology, it has been reported by Vertucci (1984)[6] that the most detailed information can be obtained by demineralization and staining technique which is regarded as an excellent method for three-dimensional evaluation of root canal anatomy.[7] Martin Trope *et al.* showed that there is difference in canal anatomy in various ethnic groups.[8] The maxillary first molars generally have three roots and can have as many as three mesial canals, three distal canals, and two palatal canals.[9] Root number and morphology of South Indian population molars were different to those in Burmese (2001)[10] and Thai (2002)[11] populations, where all first and second molars had completely three separate roots. In this study, it was observed that all maxillary first molars 100% had three separate roots, whereas in second molars only 41% had three separate roots, 42% two root fused, and 16% three roots fused.

The MB root of the maxillary first molar has undergone more research and studies than any other root in the mouth. It generally has one or two canals but a third canal has been reported.[9] Second MB canal (MB2) of South Indian population molars was different to those in Japanese (1999),[1] Burmese (2001),[10] and Thai (2002)[11] populations, where Japanese maxillary first molar present 27% of MB2 canal; Burmese population present 68% in first molar, 49% in second molar; Thai population present 65% of MB2 in first molars, and 55% MB2 in second molars. In this study, MB2 canal was found to be 84% in maxillary first molar and 38% in second molars. In the two-canalled MB roots, the Type II, IV, and VI canal systems were the most prevalent. MB2 canals are often very fine and difficult to negotiate; consequently, more errors in instrumentation occur in this tooth than any other. Anastomosis between the two canals in mesial root may take the form of narrow canals or wide fins, both making instrumentation and disinfection challenging.[12]

Accessory and lateral canals are communications between the pulp and the periodontium in the apical, middle, or coronal third of the root.[13] According to Vertucci (1984),[6] lateral canals occur most commonly in the apical third of the root (73.5%), followed by middle third (11.4%) and cervical third (6.3%). They are formed by the entrapment of periodontal vessels in Hertwig mesial root mayot sheath during calcification.[14,15] They serve as avenues for the passage of irritants primarily from the pulp to the periodontium. The observed prevalence of lateral canals in the apical third of Burmese (2001)[10] and Thai (2002)[11] populations were 13% and 10.5%, respectively. In the present study, the lateral canals were found to be highest in the apical third of MB root (51% in first molars and 40% in second molars). In this study, intercanal communications were most prevalent in maxillary first molars (MB roots - 32%). Whereas in Burmese (2001)[10] populations, it was 27% in first molars; and in Thai (2002)[11] populations, it was 16% in first and second molars.

The clearing technique being three-dimensional also reveals the bucco lingual nature of canals which are usually not discernible in the radiograph. The palatal root curvature is more commonly seen toward the buccal, and this cannot be

visualized from the radiographs.[12] As a result, the clinician may assume that a canal is straight and may over enlarge what is, in reality, a facial or lingual curvature, resulting in ledging or perforation.[16] In this study, palatal root curvature at apical third in the first molar was more commonly toward the buccal (70%), followed by palatal (4%) and straight (20%). The degree of curvature was less in maxillary first molars (average of 10°) compared to second molars (average of 20°). The greater the degree of curvature more likely is the formation of a ledge. A radiograph shows that the instrument or obturation no longer follows the original curve. Relocating and renegotiating the original canal is a problem; correcting the ledge is difficult, even if the original canal is renegotiated.[16]

Although clearing technique helps in a detailed investigation of the delicate root canal systems, it has few drawbacks. There can be distortion in the morphology of the tooth as a result of the demineralization process.[17] Moreover, the dying solution may not fully infiltrate into narrow canals and ramifications if the dimension was below the grain size of the injected dye.[18] Recent advances in imaging technology enable the use of micro-computed tomography (MCT) and cone-beam computed tomography in the study of root canal morphology. MCT has been proven to be an effective tool for visualizing the complex root canal anatomy in various studies and can be considered when in-depth morphological analysis is desired.[19,20]

CONCLUSION

The MB roots of the South Indian maxillary molar possessed a variety of canal system types, over 84% of first molars had MB2 canals and 38% in second molars. The palatal and distobuccal canal mainly had Type I canals. Prevalence of lateral canal was 51% and 41% in first and second molars, respectively, and exhibited highly in the apical third. Outcomes of non-surgical and surgical endodontic procedures are influenced by highly variable three-dimensional anatomy of teeth.

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How to cite this article: Naik KG, Sakkir N, Yaragonda VK, Asifulla M, Razvi SF. Internal Root Morphology of Maxillary First and Second Molars of South Indian Population by Canal Staining and Clearing Technique. Int J Sci Stud 2016;3(12):143-147.

Source of Support: Nil, **Conflict of Interest:** None declared.