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Root Canal Morphology of Primary Maxillary Molars - A Systematic Review

Research Article

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Abstract

Purpose: Primary molars tend to exhibit more variations in canal morphology compared to that of permanent molars. There is still a lacuna of adequate studies evaluating the morphology of primary maxillary molars in the literature. This systematic review aimed to analyze the root canal morphology of primary maxillary molars using different diagnostic aids in different ethnic population.

Materials and Methods: An exhaustive search was undertaken to identify published literature related to the root anatomy morphology of the primary maxillary molars. Using a combination of key words search was done up to April 2020 in Medline/PubMed, The Cochrane Central Register of Clinical Trials, SIGLE and Science Direct. The included data consist of type of population, number of teeth per study, number of root canals, canal length and type of root canal configuration.

Results: A total of 13 studies (951 primary maxillary molars) which met the inclusion criteria were taken up for the systematic review. Maxillary molars (1st and 2nd) showed more predominance for two roots variant. In maxillary first molar the mean root length ranges from 7.9mm – 8.1mm and in second molar it ranges from 7.2mm-8.5mm. Type I canal morphology is the most common variant in both the molars.

Conclusion: Root Canal morphology shows considerable variations with the diagnostic aid used and in different ethnic populations. Although micro ct is the most advanced imaging modalities currently available, the practical applications are yet to be determined.

Keywords: CBCT; Pediatric Endodontics; Primary Molar; Root Canal Configuration.

Introduction

There has been an increasing trend in number of endodontic therapy procedures done in primary molars compared to that of extraction. The need to maintain the primary teeth in the occlusion until exfoliation and eruption of permanent teeth is desirable, since it acts as an ideal space maintainer [1]. Understanding the canal configuration of primary molars plays a vital role the success of any endodontic therapy. The primary molars exhibit a more torturous and complicated canal morphology compared to that of permanent teeth [2].

Vertucci introduced the standardized and most widely used method for differentiating root canal variations into the eight descriptive types [2, 3]. The actual classification was proposed for permanent dentition, but it is also used in primary dentition canal morphology. It has a drawback of not including the presence of accessory canals. More recently the classification proposed by Ahmed 2020 [4] for primary tooth canal morphology had incorporated the presence of accessory canals.

There is always a lacunae of ideal diagnostic aid which is more efficient in understanding the complex morphology of root canal with a minimum radiation and which can be incorporated in the day to day clinical practice [5]. With the introduction of micro CT imaging techniques for detailed study of tooth anatomy, there is an increase in our knowledge of understanding the external and internal anatomy of the tooth structure, canal volume and accessory canals. Hence a clinician needs to regularly update the knowledge on the canal variations identified by these newer diag-

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nostic aids [2, 5, 6].

Endodontic procedure in children is not only complicated by the canal morphology and close proximity to permanent tooth germ, the behaviour management techniques also play an important role in long term success of the procedure. Ideally a short duration procedures which is less than 30 minutes are well acceptable by the children. There is a general tendency towards deterioration of children's behaviour with an increase in treatment duration [7, 8]. Therefore; the clinician should have a precise knowledge on the various morphological variations in primary teeth and proper behaviour management techniques so that the procedure can be completed in a shorter duration.

Systematic review remains at the highest level in the hierarchy of research as it allows a top down approach to locate the best evidence for any research question. Till data to our knowledge there is no comprehensive review on canal variations in maxillary primary molars, hence the main aim of our systematic review is to analyze the canal morphology of both 1st and 2nd primary maxillary molars in different ethnic population using various diagnostic aids.

Structured Question

Is there a variation in canal morphology in primary maxillary molars with different diagnostic aids and in different ethnic population?

Search strategy was based on Pub Med Central, Cochrane Database, LILACS, Science Direct, Web of Science, Google scholar and SIGLE and was completed by a manual cross-reference search.

PICO Analysis

Patient: Children (2-12yrs)
Comparison: Various diagnostic aids
Outcome: Canal morphology of primary maxillary molars
Study design: In vitro and in vivo studies

Search methods for identification of studies

For the identification of studies to be included for this review, detailed search strategies were developed for each database searched up to April 2020. The following specialized computer databases were used to retrieve articles for the review:

- Pub Med
- The Cochrane Central Register of Clinical Trials
- Science Direct
- LILACS
- SIGLE
- Google scholar
- The search term combination for electronic databases was as follows: MeSH headings, text words and word variants for "primary tooth" and "root canal anatomy" and "diagnostic aid" were combined using Boolean operator. Searches in Google scholar and grey literature were performed based on the cross reference of included articles.

Search strategy [Fig 1]

Search 1 - PubMed (MeSH terms) and (keywords)

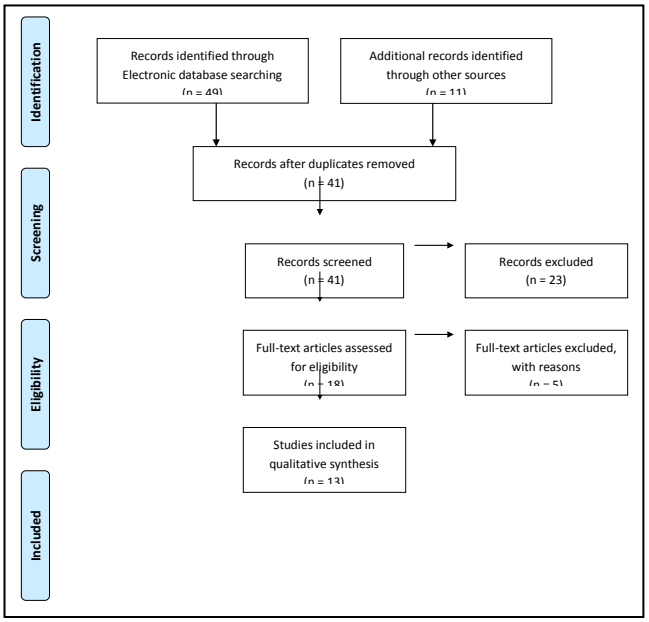
The following MeSH terms and keywords were combined with Boolean operator: ((((("X-Ray Micro tomography"[Mesh]) OR "Negative Staining"[Mesh]) OR Clearing technique) OR ("Radiography, Dental"[Mesh] OR "Radiography, Dental, Digital"[Mesh])) OR ("Spiral Cone-Beam Computed Tomography"[Mesh] OR "Cone-Beam Computed Tomography"[Mesh])) AND "Dental Pulp Cavity"[Mesh]) AND "Tooth, Deciduous"[Mesh].

Inclusion criteria

Studies were selected using the following predefined inclusion criteria.

All studies including

Figure 1. PRISMA Flow Diagram.



• *In vivo* studies
• *In vitro* studies

Exclusion Criteria

• Case reports
• Studies which has not reported on Primary Maxillary molars

Hand searching

Hand searching was done for following journals from 2000 to April 2020.

- Pediatric Dentistry
- Journal of Clinical Pediatric Dentistry
- International Journal of Pediatric dentistry
- International Endodontic Journal

Data collection and analysis

Screening and selection

Two review authors (MR and MS) independently assessed the titles and abstracts of studies resulting from the searches. Full articles of those studies which met the inclusion criteria, or for which there were insufficient data in the title and abstract to make a clear decision, were retrieved. MR assessed the full text papers independently to establish whether the studies met the inclusion criteria or not. Studies fulfilling the inclusion criteria were then underwent quality assessment and data extraction. The data was analyzed according to the ethnicity of the population and demographic status, number of teeth per study (power), number of roots present, number of root canals, method of tooth analysis, root canal patterns, and root angulations. The root canal morphology, the mean distance between central fissure and pulp chamber, and height of pulp chamber were also evaluated.

Data extraction

Data were extracted independently and in duplicate by two review authors (MR and MS). Titles of articles relevant to the review were selected by discussion. Forty one were identified from the electronic and hand searched. Abstracts and full texts of the articles were reviewed independently.

Results

The study identified a total of 951 primary maxillary molars (1st molar 451 and 2nd molar 500) in 13 published studies, out of which most of them were performed using micro-CT (n=3), CBCT (n=4), clearing technique (n=2), CT scan (n=2), spiral CT (n=1) and radiography (n=1) (Table 1).

Table 2 shows the characteristic features of each study, the number of roots and canals, angulations of the root were documented. Canal length and type of canal in each study were included.

Discussion

External and internal anatomy of the teeth is a very complex system which consists of a number of foramina which open at different locations - lateral, collateral, accessory, etc.[22] Long term clinical prognosis depends upon identification of the complexity of the canal and complete debridement. Complete canal disinfection with irrigation and intra canal medicaments are impossible if the clinician is not aware of various canal morphological variations. In any situations the presence of an untreated canal may be the most common reason for an endodontic failure [23]. As previously published in literature primary root canal showed more complex variations compared to the permanent teeth [16]. Canal variations also show great difference with ethnic population and with various diagnostic aids. Updating our knowledge from laboratory studies and use of advanced diagnostic aids is essential to

Table 1. List of Selected Studies.

Authors	Population	Methods	Study design	No of teeth 1st molar	No of teeth 2nd molar
Sarkar and Rao 2002 [9]	India	IOPA	*In vitro*	8	9
Zoremchhingi 2005 [10]	India	CT scan	*In vitro*	15	15
Bagherian 2010 [11]	Iran	Clearing technique	*In vitro*	27	14
Rajendran 2013 [12]	India	Spiral CT	*In vitro*	15	15
Wang et al. 2013 [13]	China	Micro-CT	*In vitro*	8	10
Gaurav V 2013 [14]	India	CBCT	*In vitro*	15	-
Fumes 2014 [15]	Not mentioned	Micro-CT	*In vitro*	10	10
Gozde Ozcan 2016 [16]	Turkey	CBCT	*In vivo*	81	100
Venu gopal 2018 [17]	India	CBCT	*In vitro*	18	29
Farhin Katge 2018 [18]	India	Clearing technique	*In vitro*	30	30
Dohee Sim 2019 [19]	Korea	CT	*In vivo*	208	195
Piyali Datta 2019 [20]	India	Multidetector computed tomography (MDCT)	*In vitro*	16	16
Mohd Ariffin 2020 [21]	Australia	Micro Ct	*In vitro*	-	57
Total count				451	500

Table 2. Shows the Characteristic Features of Each Study.

Authors	Inference
Sarkar and Rao 2002 [9]	**First molar:** Almost 50% of the teeth had one canal in mesio buccal root and 2 canals in the rest of the samples. 100% of the disto buccal root had one root configuration. Palatal root 75% had one canal and remaining 25% had 2 canal configurations. **Second molar:** Mesio buccal root had two canals in 66.7% of the teeth examined. Disto buccal and palatal root had single canal in 100% and 88.8% of the teeth respectively.
Zoremchhingi 2005 [10]	**First molar:** In 60% of the samples, both disto buccal and palatal roots were fused and in 40% of the samples, all the three roots were separated. The disto buccal root showed maximum root length of 7.3mm and the palatal root showed minimum root length of 6.7 mm. The palatal root had maximum angulations (41.7°) followed by mesio buccal root (39.7°) and the disto buccal root (34.2°). **Second molar:** The palatal root showed the maximum length (8.27 mm) and the disto buccal root had minimum length (8.06 mm). The palatal root also showed maximum angulations (41.5°), and the disto buccal showed the minimum angulations (34.2°).
Bagherian 2010 [11]	**First molar:** All the teeth in this group had three roots (mesio buccal, disto buccal, palatal). The palatal and disto buccal roots were fused in 77.7% of the samples. The mesio buccal (MB) root showed the maximum root length, with a mean of 8.11 mm, and the disto buccal (DB) root showed the minimum length with a mean of 6.77 mm. The mesio buccal root also showed the maximum angulations (18.66°), followed by the disto buccal root (15.40°). The palatal root (12.29°) showed the least angulations **Second molar:** All the samples of this class had three roots (mesio buccal, disto buccal and palatal).In 28.5% of the cases, the disto buccal and palatal roots were fused. The palatal root showed the maximum root length, with a mean of 9.92 mm, and the disto buccal root showed the minimum length with a mean of 7.21 mm. The palatal root had maximum angulations (16.14°), followed by the mesio buccal root (10.71°). The disto buccal root (8.78°) showed the least angulations
Rajendran 2013 [12]	The mean distance between the central fissures to the furcation was found to be 7.13mm in first primary molar and 7.38mm in second primary molar. The height of the pulp chamber was estimated to be 1.6mm in first molar and 1.71mm in the second molar. Three canal system was more prevalent in first molar (Mesio buccal, disto buccal and palatal) and 15% of the sample showed four canal system in the second molar.
Wang et al. 2013 [13]	**First molar:** Equal number of maxillary first primary molars presented two and three roots variations. Regardless of the number of roots, all maxillary first molars have three canals. Ninety percent of the mesio buccal root has single canal, whereas it was 100% in disto buccal and palatal roots. **Second molar:** Ninety percent of the second molars were three rooted, with identical numbers exhibiting three and four canal morphology. In the second molar 60% had single canal whereas 40% showed presence of 2canals in mesio buccal root alone. Approximately 80% of the maxillary molars presented an ovoid outlined root canal at the apical level. Seventy six percentage of the primary molar showed a consistent root canal outlines for the entire root length.
Gaurav V 2013 [14]	The entire maxillary molars sample exhibited 3 roots and 3 canal configuration. Mesio buccal root exhibited a mean root length of 7.75mm, disto buccal 7.61 and the palatal root estimated to be 8.03mm. In maxillary molars, the maximum diameter in each third of the root was seen in palatal canal.
Fumes 2014 [15]	**First molar:** The mean length of mesio buccal root was 7.9mm, disto buccal 6.7mm and palatal 5.9mm. The volume in the mesio buccal root was 2.8mm3 disto buccal 1.3mm3 and palatal 2.9mm3 **Second molar:** The mean length of mesio buccal root 8.5mm, disto buccal 6.5mm and palatal root was 7.4mm. Palatal root had the more volume 5.4mm3 compared to mesio buccal root (3.2 mm3) and disto buccal 1.0mm3)
Gozde Ozcan 2016 [16]	**First molar:** In the maxillary primary first molars, one canal was seen in the mesio buccal root in most of the samples. All the disto buccal and palatal roots of the maxillary molars were single-canal roots. Two root and 3 canals were seen in 7.4% of cases, two root and 4 canals in 1.2%. Three root and three canals in 59.2%, three root and four canals in 30.8% of samples. The mean root length were mesio buccal 6.9 ± 1.8, disto buccal 6.1 ± 1.6 and palatal root 7.7 ± 0.9 **Second molar:** Two root and three canals were seen in 5%, two root and four canal in 4% of the sample. Three roots and three canals is the predominant type in 50%, followed by three roots and four canals in 37% of the sample. Four root and four canal in also seen in 4% of the sample. The average root length were mesio buccal 7.2 ± 1.1, disto buccal 6.9 ± 1.5 and palatal root 8.3 ± 1.7
Venu gopal 2018 [17]	**First Molar:** Type I Single canal was prevalent in 88.9% of the teeth in mesio buccal root and 100% in both disto buccal and palatal roots. 88.8% of the mesio buccal root is curved, whereas only 61.2% of the disto buccal root showed curvature. Palatal root is straight in 77.7% of the teeth examined. **Second molar:** Type I canal configuration is seen in almost 100% of the teeth examined in all 3 roots. The shape of the canal is curved in mesio buccal (89.7%), disto buccal (69%) and palatal (72.8%) of the teeth examined.
Farhin Katge 2018 [18]	**First molar:** Mesio buccal canal was curved in 72.41% of teeth. One canal was the most prevalent type in all the three roots. Type I canal configuration was more prevalent in mesio buccal (93.10%), disto buccal (95.65%) and palatal (100%) **Second molar:** Palatal canal showed curvature in 88.89% of the cases. Mesio buccal root had Type I canal configuration in 90% of teeth and type IV in 10% teeth. Disto buccal had Type I in 100% of the teeth. Palatal root had Type I in 96.30% and Type III in 3.70% of the teeth.
Dohee Sim 2019 [19]	**First molar:** The most common type of root-canal was type 3/3 (Three separate roots and canals), observed in 55.8%, followed by type 2F/3 (Two roots- mesio buccal and fused disto buccal with palatal canal and three separate canal) observed in 39.4%. The types of canals were found to be 95.2% in type 3 canal (mesio buccal, disto buccal and palatal canal) and 4.3% type 4M canal (2 mesio buccal, 1disto buccal and 1 palatal canal). Type 4D canals were found in only 1 case.(1 mesio buccal, two disto buccal and one palatal canal). **Second molar:** Root-canal type 3/3 in 30.3% (Three separate root and canals) was the most commonly observed type, followed by type 2F/3 (29.7%) (Two roots- mesio buccal and fused disto buccal with palatal canal and three separate canals). The types of canals were found to be 60% type 3 canal, 36.9% type 4M canal, and 3.1% type 4P canal (1 mesio buccal, 1 disto buccal and 2 palatal canal)
Piyali Datta 2019 [20]	**First molar:** In the total sample 68.75% of the teeth had three roots and three canals. Only 25% of the teeth had two roots (separate MB root and fused DB with palatal root) and three canals (MB, DB, and palatal canals). Furthermore, 6.25% of the tooth had three roots (MB root, DB root, and palatal root) and four canals (MB 1, MB 2, DB, and palatal canal) The mean lengths of MB root, DB root, and the palatal root of maxillary first molars are 7.80 ± 0.48 mm, 7.10 ± 0.64 mm, and 6.72 ± 0.38 mm, respectively **Second molar:** Out of the total samples 81.25% of the teeth had three roots (MB root, DB root, and palatal root) and three canals (MB, DB, and palatal canals), 12.50% of the teeth had two roots (MB root and fused DB and palatal roots) and three canals (MB, DB, and palatal canals). In addition, 6.25% of the tooth had three roots (MB root, DB root, and palatal root) and five canals (MB 1, MB 2, DB 1, DB 2, and palatal canal). The mean lengths of MB root, DB root, and the palatal root is 8.50 ± 0.83 mm, 7.81 ± 0.71 mm, and 8.85 ± 0.98 mm, respectively
Mohd Ariffin 2020 [21]	**Second molar:** Out of the total sample 22.8% of the teeth had fusion of disto buccal and palatal roots. Of the teeth with three separate roots the most common canal type was Type I (68.2%), Type V (47.7%). Root canal morphology of palatal canal was Type I (100%). Type I (77.3%) classification was the most frequently observed for the disto-buccal root canal. For the mesio-buccal root canals, Type V (36.4%) was the most prevalent followed by Type I (27.2%). In specimens with root fusion (One mesio buccal and fused disto buccal with palatal) in the fused disto-buccal canals Type V (61.5%) was most prevalent, followed by Type VI (30.8%). For the mesio-buccal canal, Type V (53.8%) was the most prevalent, followed by Type I and IV with 15.4% each.

provide insight into the complex root canal anatomy.

Primary maxillary molars undergoing pulpectomy continue to present a unique challenge to pediatric dentist because of the tortuous and bizarre morphology of their root canal, the associated behaviour issues and need for proper isolation build up to the complexity of the procedure [8].

In the maxillary molars, the double root variant in which fusion between both the disto buccal and palatal roots is the predominant type, in first molar it ranges from 60-77% and this percentage is lesser in second molar 22.5% [10, 11, 16].

The distal and palatal root showed higher prevalence of single canal in most of the studies. Only one study done by Sarkar et al using clearing technique showed prevalence of two canal in palatal root which range around 25% in first molar and 12% in second molar. Three roots and three canals is the most common canal morphology in both the first and second maxillary molar [9, 16, 17]. Prevalence of two canal in mesio buccal root ranges from 11.1-50% of the samples [9, 16-18].

In maxillary fist molar the mean root length ranges from 7.9mm - 8.1mm in the mesio buccal root, 6.7-7.3mm in disto buccal and 5.9mm-7.7mm in palatal root [10, 11, 15, 16]. In Second molar mesio buccal root length ranges from 7.2mm-8.5mm, disto buccal 6.5mm-8.06mm, palatal root ranges from 7.4mm-9.92mm [10, 11, 15, 16].

With advancement in imaging modalities such as micro ct, the volume of the canal in 3 dimensional structure can be evaluated. The study done by fumes 15 estimated the volume in first molar to be 2.8 mm^3 in mesio buccal root, disto buccal 1.3 mm^3 and palatal root 2.9 mm^3. In the second molar the Palatal root had the more volume 5.4 mm^3 mesio buccal roots was 3.2 mm^3 disto buccal 1.0 mm^3.

Vertucci type I canal configuration is the most common morphology in all the three roots, in the first molar Type I canal configuration was more prevalent in mesio buccal (88.9%-93.10%), disto buccal (95.65%-100%) and palatal (100%). In the second molar mesio buccal root had Type I canal configuration in 90% of teeth and type IV in 10% teeth. Disto buccal had Type I in 100% of the teeth and palatal root had Type I in 96.30% and Type III in 3.70% of the teeth according to study done by Katge using clearing technique in Indian population [18].

In a study done by Ariffin in second molar using CBCT in Australian population, of the teeth with three separate roots the most common canal type was Type I (68.2%), Type V (47.7%). Root canal morphology of palatal canal was Type I (100%) [21].

Two studies evaluated the root angulations of maxillary 1st molar, one using clearing technique in Iran population Bagherian et al., 2010 [11] showed the mesio buccal root had maximum angulations (18.66°), followed by the disto buccal root (15.40°), palatal root (12.29°) showed the least angulations. while study done by Zoremchhingi et al., [10] by CT scan in Indian population showed that palatal root had maximum angulations (41.7°) followed by mesio buccal root (39.7°) and the disto buccal root (34.2°).

In the second molar the palatal root showed the maximum angulations (16.14°), followed by the mesio buccal root (10.71°), disto buccal root (8.78°) showed the least angulations (Bagherian et al., 2010). According to Zoremchhingi et al [10] the palatal root showed maximum angulations (41.5°), and the disto buccal showed the minimum angulations (34.2°).

Conclusion

Canal morphology varied with the type of diagnostic aid used and also in various ethnic populations. This systematic review guides the clinician on most common canal variations in maxillary first and second primary molar. Clinician should have an updated knowledge of root canal system and the most common variations one must keep in mind before pulpectomy procedures.

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