Original Article

Variations of Mandibular First Molar Root Canal in School Children: An Observational Study

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Background: Root canal (RC) treatment is most common and effective method for treatment of diseases related to periapical area and pulp of teeth. With the increase in age, the formation of secondary dentin, calcification of canals, and reduction of medullary cavity volume, it becomes increasingly difficult to accomplish a perfect RC treatment, hence the understanding of RC variation and changes in variation with increasing age improves the success rates. Aim: The aim of this study was to study the RC variation in the age-group of 10–14 years and to find if the gradual increase in age plays a role in increasing the complexity of RC variation. Materials and Methods: This study was carried out in Government Medical College, Patna, Bihar, India, from January 2018 to April 2019. Subjects within the age range of 10–14 years were selected conferring to predetermined inclusion and exclusion criteria. The subjects were divided into the groups according to age—Group I: 10–11 years, Group II: 11–12 years, Group III: 12–13 years, and Group IV: 13–14 years. The subjects were further divided into Group A and B according to sex to study if there is any significant difference in RC variation. Three intraoral periapical (IOPA) radiography with radiovisiography (RVG) of each subject were taken from three different predetermined angles and these IOPAs were then analyzed by three independent observers and the most agreed on value was included. The IOPAs were analyzed for the number of roots, the number of canals in each root and the variation of each RC were classified according to Vertucci's Classification. Results: The most common T of RC variation in mesial root of mandibular first molar was T IV succeeded by T II and T I. For distal canal of mandibular first molar, the most common variation was T I, followed by T II and T III. In our study we found that 98.88% of mandibular molars were having two roots. No significant difference was found in the variation of canal according to age or sex in our study. Conclusion: Hence, we conclude that no significant difference is seen in RC variation according to sex and age. As the groups we included in our study were not wide apart enough in age, a further long-term study is needed to ascertain if the complexity of RC increases with age.

Keywords: Intraoral periapical radiograph, mandibular first molar, root canal variation, Vertucci’s classification

INTRODUCTION

The first tooth erupted in the oral cavity is mandibular first molar, hence it is more likely to get caries and need root canal (RC) therapy.[1] To

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achieve success in RC therapy, a detailed knowledge of root and RC variation is needed. Mandibular first molar typically has two roots with a round or elliptical canal in the distal root and two canals in the mesial root, but infrequently, it has three with two or three canals in the mesial root and one, two, or three canals in the distal root. Though many variations have also been reported with this tooth, which includes the presence of single root, four roots, taurodontism, radix entomolaris, and radix paramolaris. The distal canal is usually straight till the apex. It has a large cross section and is oval or flattened in shape, making instrumentation easy. Usually the apical 1–2 mm of this canal curves distally up to 90°, but this is rarely a problem. In 90% of the cases mesial root remains separate as far as the foramen; in the remaining 10%, they join together at a common foramen. The mesial RCs take a more curved course with a mesial alignment immediately below the orifice and then distal in the rest of the RC.

Great variation in root and canal variation within populations, between populations, and even within the same individual are observed. To achieve success, an effective RC debridement is essential for which the knowledge of RC variation is foremost.

The RCs have been classified on various morphological features, which include number of canals from orifice to apex, number of roots, number of canals in each root, and number of isthmus.

Weine et al. in 1969, classified RC configurations within a single root for the first time. They divided it depending on the division of the main RC along its progression from the pulp chamber to the root apex and the number of canals from orifice to apex. As per Weine’s classification, the canals of tooth were divided into four Ts.

Vertucci further expanded Weine’s classification and classified RC systems into eight Ts.

Zhang et al. gave a classification based on number of roots and number of canals in each root; to his classification, three more variants were added by Silva et al.

Kim et al. divided apex into five Ts depending on the number of isthmus.

Among all these classifications, Vertucci’s classification is the one that is extensively accepted.

To study the anatomy of RCs various techniques such as dye penetration and clearing, sectioning, radiography, and cone beam computed tomography (CBCT) were used.

CBCT produces three-dimensional image of the maxillofacial skeleton and includes teeth and their surrounding tissues. The image is accurate and undistorted. Also the effective radiation dose is lower as compared to computed tomography (CT). The data relevant to RC variation of mandibular first molar are scarce and scattered, which increases the significance of this study.

The aim of this study was to evaluate the RC system of the mandibular first molars among children aged between 10 and 14 of the Patna, Bihar region, using intraoral periapical (IOPA) radiography as the hospital in which this study was conducted, did not have CBCT facility.

The subjects were further divided into four groups according to age: 10–11, 11–12, 12–13, and 13–14 to study whether the variation of RC has any significance with age. According to a recent study conducted by Hu et al., the RC variation gets more complex with increasing age. They also found that the number of roots in maxillary second premolar also significantly increased with the age, that is, in higher age-groups, the two-rooted maxillary premolars were more commonly observed than in lower age-groups. They found that in the maxillary second premolars, T I, II, and III canal variation were more common, and the complexity of RC variation increased gradually with the age and reached to a significant level at 20 years of age, and this trend reduced after the 40 years of age. Hence in our study, we wanted to closely monitor any change in the complexity of RC variation.

**Materials and Methods**

For this study, 700 children of age ranging between 10 and 14 years visiting routine outpatient department (OPD) of the Government Dental College, Patna, Bihar, between January 2018 and April 2019, were examined. Of 700 students, 360 (148 females and 212 males) subjects were enrolled in the study. Written consent was signed by the parents or attendants of all individuals. IOPA radiography was obtained for the selected tooth and was viewed by three examiners.

Inclusion criteria were as follows:

- Only fully erupted non-caries mandibular first molars were considered
- Patients aged 10–14 years
- Permanent mandibular first molars with no periapical lesions
• Root formation should be complete
• Tooth should not be carious

Exclusion criteria included the following:
• Teeth with root resorption
• Open apices
• Carious tooth
• Molars with caries involving pulp up to the furcation
• Incomplete root formation
• History of trauma or fracture with mandible
• Any developmental or congenital anomaly

The subjects were then divided into groups according to age and sex. Subjects within the age range of 10–11 years were placed in Group I. Those in the range of 11–12 years were in Group II, 12–13 years in Group III, and 13–14 years in Group IV. The purpose for making these close groups was to access the difference in the RC variation closely with the gradual increase in age and to find whether the RC variation gets more complicated with age. Two groups according to sex were further made. Group A included females and Group B included males. Males and females were then separately analyzed for the number of roots and the number of canals in each root and classification of canal type (T).

All the subjects were examined for the number of roots, and the roots were further examined for the number and classification of RCs.

Parameters included were the number of roots in each tooth, number of canals in each root, classification of canals according to Vertucci, and the presence of C-shaped canal systems. The C-shaped configurations were evaluated from orifice to the apex. The classification of C-shaped canal configuration was according to the classification by Melton et al. with Fan’s modification, which is as follows:

• Category I (C1)—continuous C-shaped RC from the orifice to the apex of the root
• Category II (C2)—one main RC and a smaller one
• Category III (C3)—two or three RCs
• Category IV (C4)—an oval or a round canal
• Category V (C5)—no canal lumen or there is one close to the apex.

Three examiners separately evaluated the images and only those readings that were consistent with two examiners were included in the final data.

All the data collected from case history, extraoral examination, and intraoral findings of the subjects were noted down. The study included both quantitative and qualitative data that were analyzed using descriptive statistics. The statistical software used was the Statistical Package for the Social Sciences SPSS Statistics version 20 (IBM HQ, Newyork, USA). The results were considered significant at a two-tailed level of 0.05.

**RESULTS**

Of 700 subjects, total 360 satisfied our selection criteria and were included in the study. Of these 360, only four, that is, 1.11% were single-rooted teeth and the rest 356, that is, 98.88% were having two roots, distally and mesially [Table 1]. Numbers of roots were then examined according to sex. Of 360 subjects, 148 were females and 212 were males [Table 2]. We found only 0.006% of females were having single-rooted mandibular first molar, and 1.42% males were having double-rooted mandibular first molar. The two groups were compared by paired t-test, and P value obtained was 1.000. The RC variation for 356 double-rooted mandibular first molar teeth was examined for both mesial and distal roots [Table 3]. Of 356 mesial canals, 38 (10.67%) were T I, 104 (29.21%) were T II, 8 (2.24%) were T III, 201 (56.4%) were T IV, and the remaining 4

| Mandibular 1st molar | Roots | (%) |
|----------------------|-------|-----|
| 360                  | 1     | 1.11 (4) |
| 2                    | 98.88 (356) |

| Sex          | Number of teeth examined | Number of roots | %            | P value |
|--------------|--------------------------|-----------------|--------------|---------|
| Females      | 148                      | 1               | 1 (0.006)    | Single root | 0.404 |
|              |                          | 2               | 147 (99.32)  |          |
| Males        | 212                      | 1               | 3 (1.42)     | Double root | 0.1836 |
|              |                          | 2               | 209 (98.5)   |          |

| Root        | T I (n = 356) | T II (n = 356) | T III (n = 356) | T IV (n = 356) | T V (n = 356) | T VI (n = 356) | T VII (n = 356) | T VIII (n = 356) | P value |
|-------------|---------------|----------------|-----------------|----------------|---------------|----------------|-----------------|------------------|---------|
| Mesial      | 38 (10.67%)   | 104 (29.21%)   | 8 (2.24%)       | 201 (56.4%)    | 5 (1.40%)     | 0              | 0               | 0                | 1.00000 |
| Distal      | 284 (79.76%)  | 36 (10.11%)    | 17 (4.77%)      | 14 (3.93%)     | 5 (1.40%)     | 0              | 0               | 0                |         |

T = type of root canal
(1.12%) were T V. We did not find any T VI, VII, or VII variations in this sample.

OF 356 distal canals, 284 (79.76%) were classified as T I, 36 (10.11%) as T II, 17 (4.77%) as T III, 14 (3.93%) as T IV, and 5 (1.40%) as T V. In this group also, we did not find any T VI, VII, or VII variations in this sample.

Of 356 distal canals, 284 (79.76%) were classified as T I, 36 (10.11%) as T II, 17 (4.77%) as T III, 14 (3.93%) as T IV, and 5 (1.40%) as T V. In this group also, we did not find any T VI, VII, or VII canals. T IV (56.24%) and T II (29.21%) are the most common canal configuration in mesial roots of first and second molars. T I (79.76) was the most common canal configuration in the distal root of mandibular first molars. Of 360 teeth, only one tooth was found to have C-shaped canal and that too in single-rooted teeth, remaining three single-rooted teeth were having one round- or oval-shaped canal, and no single-rooted teeth were found to have two canals [Table 4]. The distribution according to age-groups were also compared, and no significant difference in any age was found. In the age-group of 10–12 years, 62 subjects were included, among them 9.67% of mesial canals were found to be T I, 33.87% were T II, 1.61% were T III, 53.22% were T IV, and 1.61% were that of T V. The distal canals in this age-group were found to be T I (77.42%), T II (12.90%), T III (4.65%), and T IV (3.23%). We did not find any T V in this group [Table 5]. In Group II, subjects in the age-group 11–12 yrs were included; the total number of subjects in this group were 89. The mesial canal configuration in this group shows T I (8.99%), T II (30.33%), T III (1.12%), and T IV (59.55%), but no T V canal configuration was found in this group. The distal canal configuration found in this group was T I (79.72%), T II (10.11%), T III (3.37%), T IV (5.62%), and T V (1.12%) [Table 6].

Table 7 shows the details of one-way ANOVA test applied for comparisons between age-groups.

The Group III in Table 8 consists of subjects within 12–13 years of age. The mesial canal configuration in this group consists of 10.31% of T I, 28.87% of T II, 3.1% of T III, 56.70% of T IV, and 1.03% of T V canal. The distal canal configuration involved T I (83.51%), T II (*.25%), T III (4.12%), T IV (3.09%), and T V (1.03%).

The Group IV in Table 9 consists of subjects within age-group of 13–14 years. This is the largest group in which 108 subjects were included. The mesial canal configuration in this group consists of 12.97% of T I canal, 25.93% of T II canal, 2.78% of T III canal, 55.56% of T IV canal, and 2.78% of T V canal. The distal group consisted of 77.78% of T I canal, 10.19% of T II canal, 5.56% of T III canal, 3.70% of T IV canal, and 2.78% of T V canal. One-way analysis of variance (ANOVA) test was performed to compare the significance of age in canal configuration. Table 7 shows the details of one-way ANOVA test applied for comparisons between age-groups. The comparison between the groups and within the groups were carried out. P value came out to be 0.913, which is insignificant.

**DISCUSSION**

Mandibular first molar being one of the earliest tooth erupted in the oral cavity is more likely to get carious and require endodontic therapy, the likely successful

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**Table 4:** Out of four single-rooted teeth we found one C-shaped canal

| C-shaped canal configuration | Number of teeth |
|-----------------------------|-----------------|
| C-shaped canal continuous (C1) | 1 |
| Canal-shaped as semicolon | 0 |
| Canals that are separated | 0 |
| Oval-shaped canal | 3 |
| Total | 4 |

**Table 5:** Group I (age 10–11 years)

| Root | T I | T II | T III | T IV | T V | T VI | T VII | T VIII | P value |
|------|-----|------|-------|------|-----|------|-------|--------|---------|
| Mesial (n = 62) | 6 (9.67%) | 21 (33.87%) | 1 (1.61%) | 33 (53.22%) | 1 (1.61%) | 0 | 0 | 0 | 1.0000 |
| Distal (n = 62) | 48 (77.42%) | 8 (12.90%) | 4 (6.45%) | 2 (3.23%) | 0 | 0 | 0 | 0 |

**Table 6:** Group II (age 11–12 years)

| Root | T I | T II | T III | T IV | T V | T VI | T VII | T VIII | P value |
|------|-----|------|-------|------|-----|------|-------|--------|---------|
| Mesial (n = 89) | 8 (8.99%) | 27 (30.33%) | 1 (1.12%) | 53 (59.55%) | 0 | 0 | 0 | 0 | 1.0000 |
| Distal (n = 89) | 71 (79.78%) | 9 (10.11%) | 3 (3.37%) | 5 (5.62%) | 1 (1.12%) | 0 | 0 | 0 |

**Table 7:** Details of one-way analysis of variance test applied for comparisons between age-groups

| Source | SS | Df | MS | F |
|--------|----|----|----|---|
| Between groups | 230.08 | 3 | 76.933 | 0.17287 |
| Within groups | 7120.4 | 16 | 445.025 | |
| Total | 7351.2 | 19 | | |

The F value is 0.17287. The P value equals to 0.913166, nonsignificant at P <0.05

SS = sum of square, MS = mean square
endodontic therapy needs a detailed information of the anatomy of root and RC. Missing RC is usually due to the lack of knowledge and is the most common explanations for failure in endodontic therapy.

This study delivers information about the variation of RC of mandibular first molars among the children of age-group between 10 and 14 years, residents of the Patna, Bihar region, using IOPA and RVG dental imaging. Mandibular first molars were chosen for this study because most of the dental patients need endodontic treatment for their mandibular molars as they are the first permanent tooth that erupts. Children with the present age-group (10–14 years) have an advantage of being the most cooperative group, and also the root formation for mandibular first molar is completed till this age is attained; also due to less age, these teeth had lesser chances of being carious as compared to the adult population, which is attributed to the higher duration since eruption, hence higher exposure to cariogenic conditions.

Mandibular first molar generally has two roots, that is, mesial and distal. This study reported that 98.88% cases were found to have two roots in the mandibular first molar and only 1.11% of cases were found to have one root, but none of the cases were found to have more than three roots, although the prevalence of having three or more roots worldwide is 1.9%. The findings are consistent with the review of De Moor et al.,[24] where the overall percent of more than two roots in mandibular first and second molar taken together was found to be less than 3%. Taylor, in 1899, of England was the first to mention the three-rooted mandibular molars. According to Turner and Benjamin,[25] Asian and populations derived from Asia more commonly in the Arctic and north Asian populations have higher percentage of third root in mandibular first molar (25%–30%), and it is least common (1%) in African and European groups.

In our study, the occurrence of single-rooted mandibular first molar has no significant difference in both the sexes ($P = 1.0000$). Hence, the results suggest that no sex predilection for the presence of single-rooted molar exists [Table 8]. These results are in accordance to a study by Madani et al.[26] where they found that in Iranian population, the presence of single-rooted molars was not affected by sex.

The percentage of mandibular molars with two canals in the mesial and one in the distal root is 65%, and the presence of two canals in the distal root is 30% according to a review by De Moor et al.[24] The results of this study is consistent with those of De Moor et al.[24] as the percentage of single canal in distal root is 79.76%, but the incidence of double canal in mesial root of mandibular first molar is found to be higher in the current population, which is 85.6% in this study, which is in accordance to Madani et al.[26]

In the literature, multiple canals in the mesial root of mandibular molars have been described with an incidence of 2.07%–13.3%.[27, 28] The configuration of canal, which is the most common in mesial roots of first molars, was T IV (56.4%) and T II (29.21%).

In our study, we did not find T VI, VII, and T VIII of RC configuration. Our results are similar to those in Madani et al.,[26] they also did not find any roots with T VII and VIII, but they did find one case with T VI RC configuration; though in many studies the occurrence of T VIII in mesial roots of first mandibular molars was 0.2%–5%,[30] the variations seen are due to the difference in study methods [Table 1].

| Root | T I (%) | T II (%) | T III (%) | T IV (%) | T V (%) | T VI (%) | T VII (%) | T VIII (%) | $P$ value |
|------|---------|----------|-----------|----------|---------|----------|-----------|------------|-----------|
| Mesial ($n = 97$) | 10 (10.31%) | 28 (28.87%) | 3 (3.093%) | 55 (56.70%) | 1 (1.03%) | 0 | 0 | 0 | 1.0000 |
| Distal ($n = 97$) | 81 (83.51%) | 8 (8.25%) | 4 (4.12%) | 3 (3.09%) | 1 (1.03%) | 0 | 0 | 0 | |

| Root | T I (%) | T II (%) | T III (%) | T IV (%) | T V (%) | T VI (%) | T VII (%) | T VIII (%) | $P$ value |
|------|---------|----------|-----------|----------|---------|----------|-----------|------------|-----------|
| Mesial ($n = 108$) | 14 (12.97%) | 28 (25.93%) | 3 (2.78%) | 60 (55.56%) | 3 (2.78%) | 0 | 0 | 0 | 1.000 |
| Distal ($n = 108$) | 84 (77.78%) | 11 (10.19%) | 6 (5.56%) | 4 (3.70%) | 3 (2.78%) | 0 | 0 | 0 | |
It is seen that C-shaped canal is seen most commonly in Asian region, with the most common tooth being mandibular second molar. In our study, we found only one C-shaped canal. Many studies state that C-shaped canal is more common in female population but the one we found was in male. No significant difference in the anatomy of roots or RCs found was based on the sex of the group, which is in unison with the study conducted by Nosrat et al., their results are similar to our study.

We also compared the RC configuration in pediatric age-groups of 10–11, 11–12, 12–13, and 13–14 years, and the inter- and intragroup comparisons did not yield any statistical significant results. This may suggest that the RC configuration has no correlation with the age but a long-term, follow-up study of the same population may prove beneficial in finding if the complexity of RC configuration increases with age or remains static throughout life. In a study conducted by Hu et al., they found that with the increase in age, T I gradually decreased and T II gradually increased in maxillary second premolars, also the incidence of double RC increased with age, which became significant after 20 years of age, and the increase was significantly smaller after 40 years of age. They concluded that the shape gets more complicated with increase in age. In our study, no significant difference was found, which might be due to very small difference in the selected group; moreover also in a study by Hu et al., the significant difference could be found after the age of 20 years. Hence, a long-term follow-up study is needed to ascertain if the complexity of RC variation increases with age.

Seven methods were evaluated by Neelakantan et al., for the study of RC variation, which included CBCT, contrast medium–enhanced digital dental imaging, peripheral quantitative CT, spiral CT, plain (plain digital), tooth clearing techniques, and canal staining. According to them, tooth clearing technique and canal staining are the best methods to study RC variation, although CBCT is as accurate and can be also used.

The existence of two mesial canals has been reported in horizontally angulated dental imaging but these conventional dental imaging have the limitation of showing only two-dimensional view, whereas CBCT provides three-dimensional image with greater accuracy and precision, and hence is an encouraging tool for investigating the RC anatomy. Main drawback of CBCT when compared to conventional radiograph is the higher radiation dose. In our study, we were not able to take CBCT, which is the main limitation of this study. High number of subjects was the strongest point of this study, also to combat the observer bias, separate readings were taken by three independent observers, only the reading which were in concordance with at least two observers were included.

**Conclusion**

It is widely accepted that for the prevention of missed canals, a good preoperative dental imaging is a prerequisite, although dental imaging have their own restrictions in evaluating the number of canals. For the detection of extra canals, dental imaging should be taken from at least two different horizontal angles, careful interpretation is also essential. Hence within the limits of this study, we conclude that two roots are most common in mandibular first molars, followed by single, and three or more roots are the least common. No sex predilection is seen in root and RC variation of mandibular second molar. Vertucci’s T IV and T I are the most common configuration in mesial and distal roots of mandibular first molar, respectively.

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**Conflicts of interest**

There are no conflicts of interest.

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