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Review Article

ROOT AND ROOT CANAL MORPHOLOGY AND ITS VARIATION OF THE HUMAN MANDIBULAR CANINE: A LITERATURE REVIEW

Bhat Ganesh T.[1], Dodhiya Sonal S[2]*, Shetty Aditya[1], Hegde Mithra N.[3]
[1]Reader, Department of Conservative Dentistry and Endodontics, A.B. Shetty Memorial Institute of Dental Sciences, NITTE University, Mangalore, India
[2]Post Graduate Student, Department of Conservative Dentistry and Endodontics, A.B. Shetty Memorial Institute of Dental Sciences, NITTE University, Mangalore, India
[3]Department of Conservative Dentistry and Endodontics, A.B. Shetty Memorial Institute of Dental Sciences, NITTE University, Mangalore, India
*Corresponding Author Email: dodhiyasonal@yahoo.in

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ABSTRACT
The objective was to review the literature of the root and root canal morphology of the human Mandibular canine. Published studies cite the anatomy and morphology of the mandibular canine tooth. Individual case reports of anomalies were included to demonstrate the extreme range of variation. Almost all of the teeth in the anatomic studies were single rooted (94.8 %). The incidence of two roots (5.2 %) was extremely rare. Anatomic studies of the internal canal morphology found that a single canal was present in 89.4 % of the teeth, while 10.6 % of the teeth had two or more canals. However, the root and root canal morphology of the mandibular canine can be extremely complex and requires careful assessment. As an Endodontist, one should be aware of all the probable nooks and crannies of the complex root canal, its protean permutations, and combinations, to render the finest possible treatment. As is the case with any other treatment, endodontic therapy; if performed in the properly delineated and precise manner spells more than 99 % success rate. This review article attempts to bring out the possible nuances of the complex root canal system and various methods of reckoning with these significantly essential details.
Keywords: Mandibular canine, root canal morphology, two roots

INTRODUCTION

Canine is called the "cornerstone" of the mouth because of its location, which reflects its dual function to complement the incisors and premolars during mastication.[1] Anomalous root and root canal morphology can be found associated with any tooth with varying degree and incidence.[2] Studies done by Vertucci FJ (1984), have reported the basic anatomy of mandibular canine. It comprises of one root and one large canal cantered through its axis, but approximately 15 % of the cases reported the presence of two canals in the lower canine; very rarely was reported the presence of two different angulated roots.[3] Most of the times, all the roots have a main canal, which are instrumented and obturated during endodontic treatment.[4] Additional root canals in molar roots are common,[5-7] additional roots in mandibular anterior teeth are unusual.[1,8-10] The frequency of this anatomical variation in human dentition is not known. So, clinician must be familiar with the various pathways root canals take to the apex. In 1969 Weine *et al.*[11] provided the first clinical classification of more than one canal system in a single root. In 1996 Weine FS[12] revised the classification and classified root canal anatomy into four types as follows.

Type I: One canal with one orifice and one apical foramen (1-1)
Type II: Two canals that merge into one and exit as one canal (2-1)
Type III: One canal that divides into two and exit as two canals. (2-2)
Type IV: One canal leaving the chamber and dividing into two separate and distinct canals. (1-2)

Vertucci[13] further developed a system for canal anatomy classification using cleared teeth; they identified pulp space configurations, which can be briefly described as follows (Figure 1):

Type I: A single canal that extends from the pulp chamber to the apex (1)
Type II: Two separate canals leaving the pulp chamber and joining near the apex forming a single channel. (2-1)
Type III: A channel that leaves the pulp chamber, divides into two within the root, and unites again in a single channel. (1-2-1)
Type IV: Two separate and distinct canals extend from the pulp chamber to the apex. (2)
Type V: A canal leaves the pulp chamber and divides into two near the apex, with distinct apical foramen. (1-2)
Type VI: Two separate channels leave the pulp chamber; unite the body of the root and re divide close to the apex, with distinct apical foramen. (2-1-2)
Type VII: A channel leaves the pulp chamber, divides into two, unite in the body of the root and finally re divide on two channels near the apex. (1-2-1-2)
Type VIII: Three separate and distinct channels, extending from the pulp chamber to the Apex. (3)

The success of endodontic treatment depends on the thorough knowledge about root canal morphology and its possible anatomic variations.[2,7,14,15] So, proper diagnosis should be done. Ignorance of internal tooth anatomy leads to the failure of endodontic treatment because of lack of proper cleansing and sealing.[16-19] The root morphology and canal morphology of the mandibular canine can be extremely complex and highly variable. The prevalence of the number of roots and of

the number of canals of the mandibular canine reported in anatomic studies varies greatly in the literature. The factors that can contribute to differences observed in the various anatomic studies may be ethnicity,[20,21] age,[22-25] gender[26], unintentional bias in the selection of clinical examples of patients or teeth (specialty endodontic practice versus general dental practice), as well as study design (*in vitro* versus *in vivo*). Normal root and root canal anatomy of the mandibular canines are well documented in numerous textbooks, but there is a great deal of variation in the reporting of the incidence of anomalies. As a result, there is no consensus on the range of variation or possible anomalies. The purpose of this article was to review the literature and conduct an analysis of the variations found in studies that reported on root and root canal morphology of the human mandibular canine.

MATERIALS AND METHODS

Literature search and data extraction

An exhaustive search was undertaken to identify published literature related to the root anatomy and root canal morphology of the permanent mandibular canine. The MEDLINE database was searched via the Pub Med search engine http://www.ncbi.nlm.nih.gov/sites/entrez?db=pubmed by using the following search criteria: "mandibular canine", "root canal anatomy", "root canal morphology", "number of canals", "number of roots", "extra roots," "anomalies," and "abnormal morphology". A similar search strategy was also applied by the Cochrane Database and manual searches, including journals, conference proceedings, reference lists, other reviews and unpublished studies. No language restriction was applied to the search. Titles and abstracts were evaluated, and the relevance of each study to the anatomy and morphology of the mandibular canine was determined. Case studies were included to illustrate anomalies and genetic variation not reported in the larger anatomic studies. The data were analyzed, and weighted averages were determined for each of the following: External root morphology; Number of roots; Number of canals and apical foramina and Summary of case reports of other anomalies.

RESULTS

External root morphology

The root of mandibular canine in cross – section is wider labiolingually and narrower mesiolingually, which is larger, but similar to shape of other teeth. The developmental depressions are usually present on both mesial and distal surfaces of root. Depressions may be relatively deep and may give bifurcated root.[9,10,24,27-29] This anatomical aberrations according to some investigations and case reports are bilateral in nature.[30,31] According to Wheeler's[9] the anatomical crown length of mandibular canine is 11 mm, while root length is 16 mm, with the overall length of 27 mm.[9,24] While according to Grossman[32] it is 25 mm and Franklin S. Weine it is 24 mm.[17] The study done by Pecora *et al*[16] on 830 human extracted teeth of Brazilian population, showed the average length of mandibular canine 25.5 mm, ranging from 20.3 mm to 32.8 mm. According to Versiani MA *et al*[33], the length of the roots of mandibular canine ranged from 12.53 to 18.08 mm. According to study done by Sharma R[34] on 65 human mandibular canine with two roots, the average buccal root length was 23.0 mm and the average lingual root length was 22.7 mm. The maximum and minimum buccal lengths were 26.7 mm and 17.9 mm respectively and the maximum and minimum lingual lengths were 27.2 mm and 17.1 mm respectively. The buccal root was the larger of the two in 47.7 % of teeth and 43.1 % had roots of equal size.

Number of roots: bifurcated root

In a study conducted by Quellet R[35], the presence of the second root in mandibular canine appears in proportion of 5 % of all teeth included. A considerably lower percentage was found by Laurichesse JM *et al*.[36], which have been described that in the case of mandibular canines, the second root is found in proportion of only 1 %. Mandibular canine usually have one root, but variation may be two roots according to literature.[16,37-40] [Table 1] Green D (1955) and Kutler Y (1961) analyzed the anatomy of the endocanalicular system and reported that the presence of two roots in mandibular canines is rarely seen.

Number of canals

The incidence of a single canal is 89.4 %. In the single-canal system, 96.9 % have a single apical foramen.[3,16,42-44] The bifurcated root canals are not uncommon for mandibular canine.[9,45,46] According to literature, various studies done in various country, using different methods have found prevalence of two canals in mandibular canine.[3,16,26,39,40,42,43,47-53] [Table 2] When two canals are present in a single-rooted mandibular canine, the most common configuration is the joining of the two canals before exiting at the apex (Vertucci Type II (2-1) or Vertucci Type III (1-2-1). The studies conducted by several authors[26,42,40,52] classified mandibular canine, according to their canal variation, using Vertucci's classification. [Table 3]

Summary of Case Reports of Other Anomalies

Other anomalies documented in case reports areas as follows:

- Two separate roots and two canals – total 13 case reports[1,2,8,17,21,54-61]
- 1 root and 2 canals – total 5 case reports[31,62-65]
- 3 canals and two roots – total 3 case reports[66-68]
- There has been reported case of densinvaginatus,[69,70] and densevaginatus of mandibular canine.[71]
- There is one reported case of fused mandibular lateral incisor with mandibular canine.[72] And one case report of Radiculomegaly of mandibular canine in patient with Oculo-facio-cardio-dental (OFCD).[73,74]

Careful evaluation of two or more differently angulated periapical radiographs is mandatory to locate any morphological variation of tooth.[75-77] Radiographs, however, may not always determine the correct morphology particularly when only a buccolingual view is taken.[77] Using the 'fast break' guideline that disappearance or narrowing of a canal infers that it divides resulted in failure to diagnose one-third of these divisions from a single radiographic view. The evaluation of the root canal system is most accurate when the dentist uses the information from multiple radiographic views together with a thorough clinical exploration of the interior and exterior of the tooth.[78]

Table 1: No. Of Roots in Mandibular Canine

Number of Studies cited	Number of Teeth	One root	Two Root
5	6926	95.69 %	4.31 %

Table 2: No. Of Root Canals in Mandibular Canine

Author (s)	Type of Study	Country	1 Canal (%)	2 Canals (%)	3 Canals (%)
Vertucci[3]	Clearing	USA	94	6	
Pecora *et al*[16]	Clearing	Brazil	97.1	2.9	-
Sert and Bayirli[26]	Clearing (men) (women)	Turkey	100 97	 3	
Ona Cella Andrei[39]	Radiography – *in vivo*	Roman	94.92	5.08	
Mohsen Aminosobhani[40]	CBCT	Iran	71.98	28.2	
Caliskan et al[42]	Clearing	Turkey	98	2**	
Pineda and kuttler[43]	Radiographic	Maxico	95	5	
Green[47]	Ground sections and microscopes	USA	97	3	
Saeed rehimi[48]	Clearing	Iran	87.92	12.08	
Hession *et al*[49]	Contrast and Radiographic		91	9	
Belizzi and Hartwell[50]	Radiographs and RCT		95.9	4.1	
Kaffe *et al*[51]	Radiography – in vivo		86.25	13.75	
P. Bakrianian Vaziri[52]	Tooth sectioning	Iran	88	12	
Miyoshi S *et al*[53]		Japan	93.7	6.3	
** percentage of cases in which one canal divided to form two					

Table 3: Root Canal Classification (Verticci's) of Mandibular Canine in percentage value

Authors	Type of study	Type I	Type II	Type III	Type IV	Type V
Frank J. Vertucci (1974)[13]	Clearing	78	14	2	6	
Semith Male		90	9			
Sert[26] Female	Clearing	62	22	13	3	
M. Aminosobhani[40] Male	CBCT	36 ± 0.3	5.1 ± 0.2	1.4 ± 0.1	6.4 ± 0.2	1.3 ± 0.1
Female		35.8 ± 0.1	5.2 ± 0.2	1.4 ± 0.1	6.4 ± 0.1	1.0 ± 0.2
M. K. Caliskan *et al*[42]	Clearing	80.39	3.92	13.73		
Saeed *et al*[48]	Clearing	91.60	6.11	2.29		
P.B. Vaziri[52]	Tooth sectioning	88	5	7		

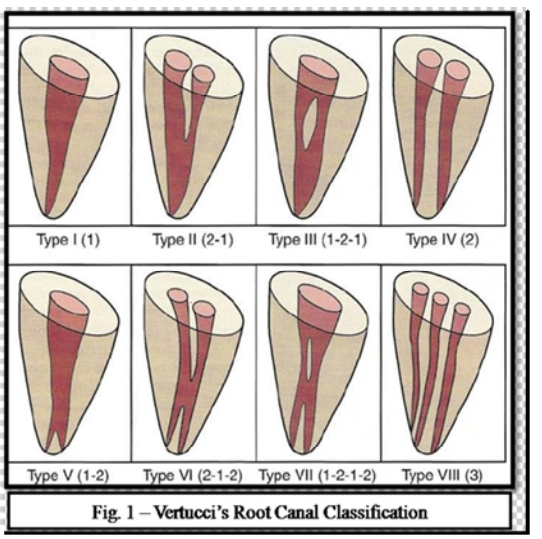

Fig. 1 – Vertucci's Root Canal Classification

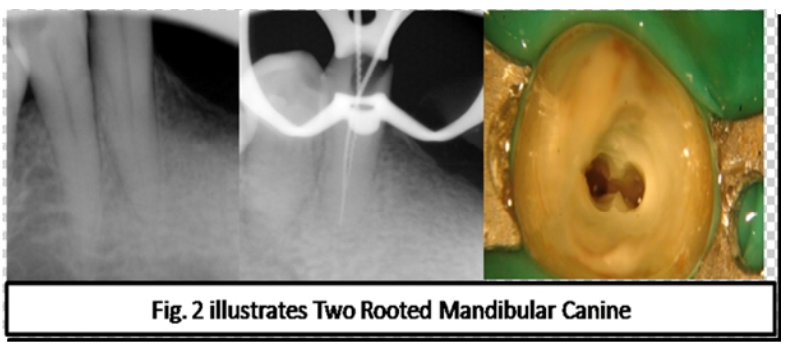

Fig. 2 illustrates Two Rooted Mandibular Canine

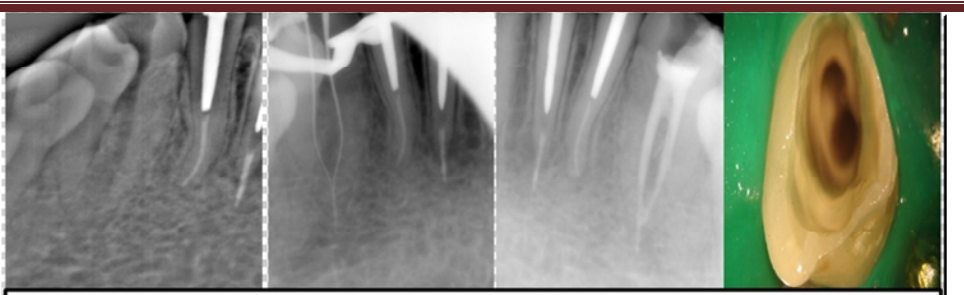

Fig. 3 Illustrates 1-2-1 canal configuration of case 1

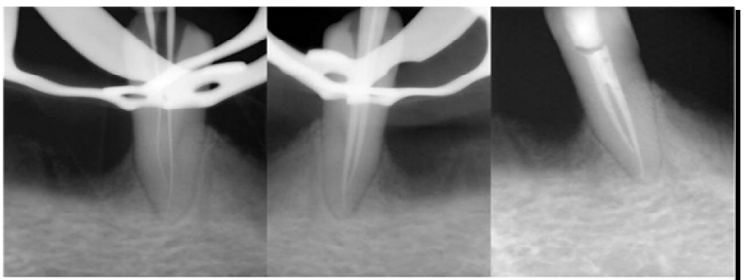

Fig. 4 Illustrates 1-2-1 canal configuration of case 2

DISCUSSION

With respect to the root and root canal morphology of teeth, the human mandibular canines are no exception. Mandibular canines are recognized as usually having one root and one root canal in the majority of cases (Laurichesse *et al* 1986). Pineda and Kuttler (1972), Green (1973) and Vertucci (1984) reported that 15 % of mandibular canines presented with two canals with one or two foramina. The clinician must be familiar with the various pathways that root canals take to the apex. The pulp canal system is complex and canals may branch, divide and rejoin. The anatomies of mandibular canine have been examined extensively (Pecora *et al*, Vertucci, Caliskan *et al,* sert and Bayirli, Pened and Kuttler, Green, P. Bakrianian, Hession *et al*, Belizzi and Hartwell, Kaffe *et al*, Saeed rehimi, Ona Cella Andrei and Mohsen Aminosobhani). Diagnostic measures such as multiple pre-operative radiographs[79], examination of the pulp chamber floor with a sharp explorer, toughing of grooves with ultrasonic tips, staining the chamber floor with 1 % methylene blue dye, performing the sodium hypochlorite 'champagne bubble' test and visualizing canal bleeding points are important aids in locating root canal orifices. An another important supplementary aid for locating root canals is the dental-operating microscope (DOM) which was introduced into endodontics to provide enhanced lighting and visibility. It brings minute details into clear view. It enhances the dentist's ability to selectively remove dentine with great precision thereby minimizing procedural errors. Recently, cone beam computed tomography (CBCT) / Multi Slice computed tomography (MSCT) has been introduced as an improvement of the diagnostic tools available for dental applications.[14,40,59,80,81] CBCT provides the clinician the ability to view an area in three different planes and to gain three dimensional information. The combination of sagittal, coronal, and axial views in CBCT images eliminates the superimposition of anatomic structures. Root morphology, the number of root canals and their convergence or divergence from each other can be visualized in three dimensions.[14,40] Although various case reports have been reported for incidence of two roots and two separate canals in mandibular canine, we also encountered cases of mandibular canine with variation in roots and canals.

Case Report 1: [Figure 2]

A 46 years female patient was referred to the department of Conservative Dentistry and Endodontic, for the pulp space therapy of a mandibular left canine (33). The tooth was clinically healthy and sound. A preoperative radiograph from two different horizontal angulations was showing two distinct root outlines. The tooth was anaesthetized and rubber dam (Hygenic Dental Dam, Colte´ne Whaledent, Langenau, Germany) was placed, followed by access was gained via the lingual approach using high speed Endo access bur No.1 (Dentsply/Maillefer). The working lengths for both buccal and lingual canals were estimated using electronic apex locator (Propex II) and confirmed by radiographs. The root canal configuration consisted of two separate roots with two separate canals leaving the floor of the pulp chamber, exiting from two individual foramina. Working length was 19 mm on lingual canal and 17.5 mm on the buccal one. Canal orifices were located using endodontic microscope (Carl Zeiss, OPMI pico). The root canals were prepared using ProTaper-6 % (Dentsply Maillefer, Ballaigues, Switzerland) nickel–titanium (NiTi) rotary instruments with X-Smart endodontic motor till finishing file F2 (Dentsply/Maillefer) and were copiously irrigated with 5.25 % sodium hypochlorite (NaOCl) and 17 % ethylene-diaminetetraacetic acid - EDTA (Glyde, Dentsply/Maillefer). Canals were dried using paper points. Pro Taper master cone No.F2 (Dentsply/Maillefer) gutta-percha point was checked for apical fit in both the canals. Canals were obturated with resin based sealer (AH Plus) using the cold lateral compaction technique. Post obturation radiographs showed two well obturated canals ending at the radiographic apex. Tooth was temporized using CAVIT. Patient was asymptomatic on recall.

Case Report 2

Case 1 [Figure 3]

A 43 years female patient was referred to Conservative Dentistry and Endodontic from Prosthodontic Department of A.B. Shetty Memorial Institute of Dental Sciences, for

intentional Root Canal Treatment of mandibular left canine (33). The tooth was clinically healthy and sound. A preoperative radiograph from two different horizontal angulations was showing single canal bifurcating into two canals at the junction of cervical and middle third of root canal and again meeting as a one canal at apical third of root canal. The tooth was anaesthetized and rubber dam (Hygenic Dental Dam, Colte´ne Whaledent, Langenau, Germany) was placed, followed by access was gained via the lingual approach using high speed Endo access bur No.1 (Dentsply/Maillefer). Entry was made into the pulp chamber and access cavity modified to oval shape wider bucco-lingually. First 8 number K-file was inserted till the apex and a second 8 number K file was inserted in the same orifice which advanced lingual to the previous file. The working length was estimated using electronic apex locator (Propex II) and then confirmed by radiograph. The radiograph suggested that canal was single at the orifice, bifurcated at the junction of cervical and middle third and united as single just before reaching apical foramen suggesting 1-2-1 root canal configuration. Canal orifices were located using endodontic microscope (Carl Zeiss, OPMI pico). The root canals were prepared with pro taper rotary instruments and were copiously irrigated with 5.25 % sodium hypochlorite. Root canal dried using paper points. Pro taper master cone gutta-percha was seated and checked for apical fit individually for both the canals. While obturating, the labial variant of the bifurcated canal was done first. Master gutta percha cone was coated with sealer and introduced in to the labial branch up to the working length. Then corresponding heated Calamus Electric Heat Plugger (EHP) was used to sear off the master cone at the level of the orifice. EHP was introduced into the canal from orifice at the temperature of 200 degrees for 2 seconds and advancing towards just below the level of bifurcation. Then again the heat was activated for 1 sec and plugger was withdrawn searing gutta-percha along with. Subsequently the same procedure was carried out to obdurate the lingual branch of bifurcated canal till the level of bifurcation. Then rest of the canal was back filled with Calamus Flow delivery system. Tooth was temporized with CAVIT. Post obturation radiograph was taken. Patient was recalled after one week for permanent restoration.

Case 2 [Figure 4]

A 48 years female patient was referred to Conservative Dentistry and Endodontic from Prosthodontic Department of A.B. Shetty Memorial Institute of Dental Sciences, for intentional Root Canal Treatment of mandibular left canine (33). The tooth was clinically healthy and sound. A preoperative radiograph from two different horizontal angulations was showing single canal bifurcating into two canals at the junction of cervical and middle third of root canal and again meeting as a one canal at apical third of root canal (Figure 2a). Canal orifices were located using endodontic microscope (Carl Zeiss, OPMI pico) (Figure 2b). Biomechanical preparation was done same as in case 1 and master apical cone fit (Figure 2c) was taken, followed by obturation using calamus (Figure 2d) same as in case 1.

CONCLUSION

The mandibular canine has a large volume pulp. The situations that can create difficulty are the presence of two canals or the unusual occurrence of two roots, but this is rare. Undetected roots and canals will involve the lack of filling of this endodontic space, which will lead to endodontic treatment failure. So the preoperative radiograph is of utmost importance. One should take radiographs with varying angulations to rule out extra roots/canals. This review highlights the importance of having a detailed knowledge of all possible root and root canal configurations, followed by proper endodontic treatment of the same.

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