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# ISTRAŽIVANJE KONFIGURACIJA KANALA KORENA DRUGOG MANDIBULARNOG MOLARA I NJIHOVA BLIZINA MANDIDULARNOM KANALU: ANALIZA POPREČNOG PRESEKA KOMPJUTERIZOVNE TOMOGRAFIJE KONUSNOG ZRAKA

# EXPLORING MANDIBULAR SECOND MOLAR ROOT CANAL CONFIGURATIONS AND THEIR PROXIMITY TO MANDIBULAR CANAL: A CROSS-SECTIONAL CONE-BEAM COMPUTED TOMOGRAPHY ANALYSIS

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***Sažetak***

***Cilj:*** *Cilj ove studije bio je da se proceni konfiguracija kanala korenova drugih donjih molara u odnosu na mandibularni kanal primenom kompjuterizovne tomografije konusnog zraka (engl. Cone Beam Computed Tomography – CBCT) u populaciji savezne države Andra Pradeš u jugoistočnoj Indiji.*
***Materijali i metode****: Analizirana su sto trideset četiri CBCT snimka drugih donjih molara radi utvrđivanja Vertučijeve klasifikacije kanala, broja korenskih kanala, udaljenosti mandibularnog nervnog kanala od apeksa korenova, stepena zakrivljenosti korenova, učestalosti pojave dodatnih korenova i prisustva kanala u obliku slova C. Povezanost između starosti i udaljenosti mandibularnog nervnog kanala od apeksa korenova procenjena je $X^2$ testom, sa nivoom statističke značajnosti $p < 0,05$. Analiza podataka sprovedena je uz pomoć softverskog paketa IBM SPSS, verzija 23.0.*
***Rezultati:*** *Tri korenska kanala identifikovana su u 94,7% drugih donjih molara. U mezijalnom korenu najčešće je bila zastupljena konfiguracija tipa V, za kojom sledi konfiguracija tipa IV; u distalnom korenu dominirao je pak tip I. Prosečan stepen zakrivljenosti iznosio je 23,48°. Konfiguracije kanala u obliku slova C sa sraslim korenovima uočene su kod 5,3% ispitanika. Srednja udaljenost od apeksa mezijalnog korena do mandibularnog kanala iznosila je 3,66 mm, a udaljenost od apeksa distalnog korena 2,98 mm, što ukazuje na to da je distalni koren bliži mandibularnom kanalu nego mezijalni. Takođe, prosečna udaljenost bila je manja kod žena nego kod muškaraca. Što su ispitanici bili stariji, to je udaljenost između apeksa korena i mandibularnog nervnog kanala bila veća.*
***Zaključak:*** *Ova studija ukazuje na anatomske varijacije drugih donjih molara koje su od ključnog značaja za uspešno sprovođenje endodontskog lečenja, ali i za forenzičku analizu, s obzirom na to da se morfologija korenova može razlikovati u zavisnosti od geografske pripadnosti, rase i pola pacijenata. Razumevanje ovih etničkih varijacija može dovesti do toga da kliničari optimizuju terapijski pristup, kako bi ishodi lečenja pacijenata bili bolji.*

***Ključne reči:*** *drugi donji molari, zakrivljenost kanala, korenski kanal u obliku slova C, mandibularni kanal, morfologija korenskih kanala, koren*

***Abstract***

***Aim:*** *The study aimed to assess the canal configuration of mandibular second molar roots and their relationship to the mandibular canal using Cone-Beam Computed Tomography (CBCT) in the Andhra Pradesh population.*
***Materials and Methods:*** *One hundred and thirty-four CBCT-scans of mandibular second molars were examined to determine Vertucci's canal configurations, number of root canals, distance of mandibular nerve canal from the root apices, degree of curvature of roots, incidence of additional roots, and C-shaped canals. The relationship between age and distance from the mandibular nerve canal to root apices was assessed using the chi-square test, with a significance level set at $p < 0.05$. Data analysis was conducted using IBM SPSS Version 23.0.*
***Results:*** *Three root canals were identified in 94.7% of mandibular second molars. In the mesial root, Type V was the most common canal configuration, followed by Type IV, while Type I was predominant in the distal root. The average curvature was 23.48°. C-shaped canal configurations with merged roots were observed in 5.3% of patients. The mean distance from the mesial root apex to the mandibular canal was 3.66 mm, whereas the distance from the distal root apex was 2.98 mm, indicating that the distal root was closer to the mandibular canal than the mesial root. Additionally, the mean distance was shorter in females than in males. As age increased, the distance from the apices of the root to the mandibular nerve canal also increased.*
***Conclusions:*** *This study highlights anatomical variations of the mandibular second molar crucial for successful endodontic treatments and also helps in forensic analysis as root morphology can differ based on geographic location, patient's race and gender. By understanding these ethnic variations, clinicians can optimize treatment strategies for better patient outcomes.*

***Key words:*** *mandibular second molars, canal curvature, C-shaped root canal, inferior alveolar canal, root canal morphology, radix*

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## *Introduction*

Understanding root canal anatomy, including the number of roots, the number and position of canals in each root, the cross-sectional dimensions, the prevalent curvatures (particularly in buccolingual sections), and the overall outline form in all dimensions, is crucial for successful root canal treatment[1–3]. A lack of knowledge about pulp anatomy and canal variations can lead to treatment failures. Therefore, it is essential to be well-versed in both the typical anatomy of the pulp and the potential variations. Familiarity with the different types of normal and abnormal pulpal anatomy allows dentists to prepare special techniques tailored to the specific anatomy encountered[4,5].

The anatomical arrangement of roots and canals in first and second mandibular molars is diverse[5–9]. Typically, these molars have roots that are positioned mesiodistally and three root canals (mesiobuccal, mesiolingual, and distal). Consistent anatomical features within specific tooth types and among different races suggest a genetic basis for these traits[10,11]. Studies in diversified populations often show a high proportion of Vertucci's Type II canal configurations in mesial roots. However, in second mandibular molars of Asians with mesial and distal roots, Vertucci's Type IV is commonly found in mesial roots and Type I in distal roots6. The internal and external anatomy of mandibular second molars varies significantly according to race and geographic origin[12–15]. Although dissimilarities in the anatomy of second mandibular molars' root canal have been well-recognized in some populations[16–19], it is now well-known that root canal anatomy is influenced by ethnic factors, highlighting the importance of identifying root canal morphologies specific to different racial types[20]. Additionally, forensic dental identification is crucial in determining the identity of unidentfied individuals because of the distinctive dental patterns associated with different races. Dental records have been utilized to identify victims in mass disasters, including the September 2001 terrorist attacks and the 2004 Indian Ocean Tsunami, where dental information identified approximately 80% of non-Thai victims in Thailand[21]. The relative position of the second mandibular molars to the mandibular nerve canal and its correlation with the patient's age is also crucial.

Any damage can be caused to the Inferior Alveolar Nerve (IAN) during various endodontic procedures. Various proposed mechanisms include neurotoxic effects from root canal filling materials that penetrate the IAN, mechanical pressure on the nerve due to overextension of filling materials, over-instrumentation with hand or rotary files, or an increase in temperature near the IAN exceeding 10 °C. These factors can lead to mechanical or chemical damage to the mandibular nerve, making the positioning relative to the mandibular canal crucial[21].

The primary etiological factor in the development of a C-shaped root configuration is the failure of adhesion of Hertwig's epithelial root sheath to the buccal and lingual root surfaces[22]. The prevalence of C-shaped root canals in mandibular second molars varies widely, ranging from 2.7% to 44.5%, depending on the population studied[23,24]. This indicates that there are ethnic variations in the prevalence of C-shaped root canal configurations.

CBCT is a non-invasive and highly precise technique with numerous advantages for epidemiologic endodontic research[22,24]. These benefits include the reduction or elimination of superimposition of adjacent structures, three-dimensional reconstruction in axial, coronal, and sagittal planes[24], high precision, fast scanning speed, and a low radiation dose[22,24]. CBCT can produce images of multiple teeth with a radiation dose comparable to that of two periapical radiographs[25]. Due to the scarce literature on the morphological variations in root canal configurations of second mandibular molars and their affiliation to the mandibular nerve canal in the Andhra residents, this CBCT study was conducted to assess the canal configurations of second mandibular molars and their proximity to the mandibular nerve canal in this demographic area.

## *Materials and Methods*

This study was approved by the Ethics Committee (IECVDC/23/PG01/OMR/IVT/69), and the scans were gathered from patients who visited Vishnu Dental College and Hospital Bhimavaram, from March 2022 to February 2023. These patients were recommended to undergo CBCT imaging for diagnostic reasons unrelated to this study, including the surgical extraction of impacted teeth, orthodontic treatment planning, implant planning, or other pathological maxillofacial conditions.

### *Inclusion and Exclusion Criteria*

We included 134 CBCT scans in the study performed with a CBCT unit CRANEX 3D with a flat panel detector. The scan was set at 90 kV and 10 mA as recommended by the manufacturer, with different fields of view (FOV) 61 x 41 mm and 61 x 78 mm with standard resolution of 200 μm and 300 μm voxel size, respectively. The scans were of sufficient quality for diagnostic purposes, free of artifacts, and showed fully erupted permanent second molars without any periapical lesions and patients in the age range of 15–60 years, were included. The study excluded teeth with certain conditions, such as incomplete root formation, mesial drift of permanent third molars, generalized disorders, open root canal apices, resorption and calcification of second mandibular molars, as well as those with root canal fillings, posts, and crown restorations.

The CBCT-generated radiographic images were analyzed according to the parameters of the present research. The root canal patterns were evaluated and classified based on Vertucci's 1984 classification[26], as follows:

Type I—One canal runs all the way from the pulp chamber to the apex.

Type II—Two canals begin from the pulpal chamber and merge near the apex to form a single canal.

Type III—Single canal leaving the pulp chamber, within the root splits into two, and then merges into one canal at the apex.

Type IV—Two canals extend from the pulp chamber to the apex.

Type V—one canal leaves the pulp chamber and splits into two individual canals with a distinct foramina at the apex.

Type VI—Two canals exit the pulp chamber, join in the middle, and then split again to distinct canals with two apical foramina.

Type VII—Single canal exits the pulp chamber, splits and unites within the canal, and then divides again into two separate canals near the apex.

Type VIII—Three separate canals are present within one root.

For C-shaped canals, Fan et al.[27] classification was employed. The canals were categorized as:

C1—C-shaped canal, continuous without any divisions

C2—A semicolon-shaped canal, where dentine separates one canal from another, and a C-shaped buccal or lingual canal

C3—Comprising two or more distinct canals

C4—One round or oval-shaped canal

C5—Canal lumen was not visible.

### *Evaluation of Data*

CBCT scans were obtained, and the Digital Imaging and Communications in Medicine (DICOM) files of these scans were evaluated in sagittal, coronal, and axial sections. The scans were assessed for the following parameters: the distance of the root apex of mandibular second molars from the mandibular canal in sagittal sections (Figure 3A), the number of root canals in axial sections (Figure 3B), the configuration of the root canal system in sagittal (Figure 3C) and coronal sections, the presence of any extra roots (radixes) in mandibular second molars in axial sections, and C-shaped canals in axial and coronal slices (Figure 3D). Additionally, the degree of curvature in any of the root canals was evaluated in sagittal or coronal sections (Figure 3E).

The CBCT scans were categorized into three age groups: Group I—below 30 years of age, Group II—31 to 50 years of age, and Group III—above 50 years of age. The distance from the root apex to the mandibular canal was calculated for each group.

### *Statistical Analysis*

The study examined the total number of roots and root canals, root canal configurations, the incidence of anatomical variations in root canal configurations, the degree of root curvature, the distance from the root apex to the mandibular canal, and correlations between these occurrences in males and females. The data were statistically analyzed using the Pearson chi-squared test, Fisher's exact test, and ANOVA in IBM SPSS Version 23 for Windows, with significance set at $p < 0.05$.

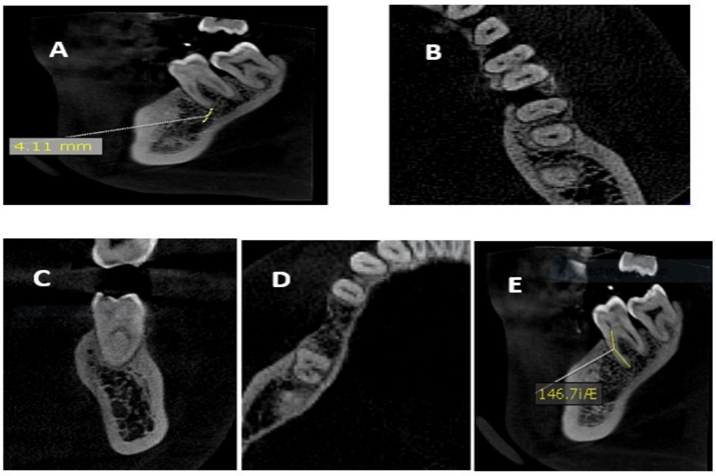


***Figure 3.*** A) Sagittal section showing distance of mandibular canal from apices of second mandibular molar roots B) Total number of root canals in axial sections. C) The root canal system configuration in sagittal section. D) C-shaped canal present in mandibular second molar. E) Degree of curvature of second mandibular molar roots in sagittal section

## *Results*

A total 134 CBCT scans with one tooth per scan were evaluated, out of them 73 (54.5%) were males and 61 (45.5%) were females.

### *Number of Roots and Root Canals*

Among 134 mandibular second molars examined, the most common morphology identified was the presence of two distinct roots positioned mesiodistally, accounting for 94.7% of cases, while fused roots were present in 5.3% of cases.

Vertucci’s classification was employed to categorize root canal configurations of mesial and distal roots of these mandibular second molars. In two-rooted molars, the most common pattern in mesial roots was Type V, followed by Type IV, while Types I, II, and III were less frequent. Most of the distal roots exhibited Type I canals (Table 1).

The prevalence of C-shaped canal in lower second molar among 134 CBCT scans was 5.3%, cross-sectional canal configuration according to Fan et al. observed in the coronal third was C3b (3%) followed by C1(1.5%), the middle third C3b (3%), followed by C2 (2.2%), apical third C3b (2.2%) followed by C2 and C4 (1.5%). Mandibular second molar root canals persisted some degree of curvature with a mean curvature of 25.88° ± 12.09°, and the range was between (0–45°).

***Table 1.*** Root canal configuration

| ROOT | VERTUCCI’S CLASSIFICATION | MALES | FEMALES | TOTAL PERCENTAGE |
|---|---|---|---|---|
| | TYPE I | 3 (2.4%) | 10 (7.9%) | 13 (10.2%) |
| | TYPE II | 10 (7.9%) | 7 (5.5%) | 17 (13.4%) |
| MESIAL | TYPE III | 10 (7.9%) | 2 (1.6%) | 12 (9.4%) |
| | TYPE IV | 25 (19.7%) | 15 (11.8%) | 40 (31.5%) |
| | TYPE V | 24 (18.9%) | 21 (16.5%) | 45 (35.4%) |
| DISTAL | TYPE I | 72 (56.7%) | 55 (43.3%) | 127 (100%) |

***Association of the Distance of the Root Apex from the Mandibular Canal and Age***

The study found that the distance between the root apex and the mandibular canal tended to increase with age. Specifically, Group III (> 50 years) had the largest distances (mesial root 4.06 mm, distal root 3.42 mm), followed by Group II (31–50 years) (mesial root 3.71 mm, distal root 3.03 mm), and Group I (≤ 30 years) (mesial root 3.62 mm, distal root 2.95 mm). However, statistical analysis using the chi-square test showed that this association between age and distance was statistically insignificant for both the mesial root ($p = 0.538$) and distal root ($p = 0.889$) from the mandibular canal. This suggests that although there is a trend of increasing distance with age, it is not significant enough to establish a clear relationship between age and the distance of the roots from the mandibular canal (Figure 1).

***Association of the Distance between the Root Apex and the Mandibular Canal and Sex***

The study examined the relationship between gender and the distance between the root apex and the mandibular canal. It was found that males had a mean distance of 3.81 mm for the mesial root and 3.16 mm for the distal root, while females had a mean distance of 3.66 mm for the mesial and 2.98 mm for the distal root. Statistical analysis using the chi-square test revealed that there was no statistically significant association between males and females regarding the distance of the mesial root ($p = 0.425$) or distal root ($p = 0.228$) apex from the mandibular canal. However, it was observed that the distance from the root apex to the mandibular canal tended to be greater in males compared to females (Figure 2).

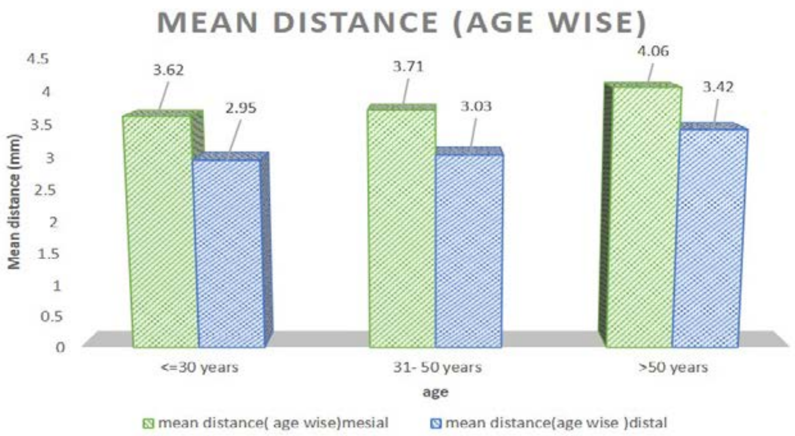


***Figure 1.*** Age-wise difference in average distances between the mesial and distal root apex from the mandibular canal


***Figure 2***. Average distance of both the root apices from the mandibular canal between the two genders

## *Discussion*

Mandibular second molars are known for their significant variations in patterns of root and canal morphologies. The present study investigated the second mandibular molars' root canal anatomy and their relationship to the mandibular nerve canal in Andhra residents. Studies conducted in Europe, North America, and Australia reported that patients of Asian descent displayed diverse proportions of canal configurations compared to ethnic groups from other continents[28].

The most frequently observed morphology of the roots was the existence of two distinct roots, accounting for 94.7% of cases. This finding is consistent with the results of 76% in the Asian population reported by Maning et al., and in 87.8% of the Indian population found by Neelakantan et al.[29]. However, it differs from the study conducted by Gulabivala et al.[7], which reported a 58.2 occurrence in the Burmese population. Additionally, this study found no mandibular second molars with three roots, which aligns with Gulabivala et al's[7] findings in the Burmese population, where three-rooted mandibular second molars were also absent. In contrast, the study by Kantilieraki et al.[30] on the Greek population reported a 4.9% incidence of three-rooted mandibular second molars.

In two-rooted mandibular second molars, the most commonly observed root canal pattern in the mesial root was Vertucci's Type V, occurring in 35.4% of cases, followed by Type IV in 31.5%. This is consistent with Gulabivala et al.'s study on the Thai population[8], which found Type IV in 57.4% of cases. However, it contrasts with Ingle et al.'s[3] study on the American population, where 49% of mesial roots exhibited Vertucci's Type II, and Shah N. et al.'s study on the Gujarat population, where 57.7% of mesial roots showed Vertucci's Type II. These differences in root canal configurations can be attributed to geographical variations among populations.

The distal roots predominantly displayed Vertucci's Type I configuration in 94.7% of cases. This finding aligns with Dae Pablo et al.[31] systematic review, which analyzed around 22 studies and found Type I to be the most common configuration in 62.7%. It is also consistent with the study by Neelakantan et al.[29] on the Indian population, where 77.7% of distal roots exhibited Type I canal configuration.

The incidence of C-shaped canals with merged roots of 5.3% in our study is comparable to a study by Singh RD[32] et al., which reported 6.72% in the North Indian population. However, this is lower than the 14% found by Shah N. et al. in the Gujarat population. These variations within the Indian subcontinent underscore the need for population-specific studies. According to Fan et al.'s classification, the most common cross-sectional canal configuration in our study was C3b (3%) in the coronal third, followed by C1 (1.5%); in the middle third, it was C3b (3%), followed by C2 (2.2%); and in the apical third, it was C3b (2.2%), followed by C2 and C4 (1.5%). This contrasts with the findings of Wadhwani S. et al.[33] in the Turkish population, where the common coronal level canal configuration was C1 followed by C2 with 3.1% and 2.3%, respectively.

The average distance from the mesial root apex of the mandibular second molar to the mandibular canal was 3.66 mm, and for the distal root apex, it was 2.98 mm. These findings are similar to those of Aljarbou et al.[34] in the Saudi population, which reported distances of 2.33 ± 2.16 mm for the mesial root and 1.68 ± 1.98 mm for the distal root. Another study by Lvovsky et al.[35], which used CBCT to measure the distance between the root apex and the inferior alveolar canal in three different populations, found significant differences: 4.60 mm in Israel, 5.45 mm in South Korea, and 4.35 mm in India. These variations highlight that different ethnic groups and populations may have distinct craniofacial characteristics affecting the spatial relationship between mandibular second molar roots and the inferior alveolar nerve. Genetic predispositions and evolutionary adaptations likely contribute to these differences.

Our study observed that females generally have shorter distances to the mandibular canal compared to males. This is consistent with the findings of Simonton et al.[36] in the Texas population, which reported the distances of 4.9 ± 2.2 mm for females and 6.2 ± 2.6 mm for males, indicating that females consistently have shorter distances. This difference may be due to the larger body size typically seen in males, which can result in greater distances between the mandibular canal and root apices. Clinically, this suggests that females may be at a higher risk of iatrogenic nerve injury compared to males[36].

The distance from root apices to the mandibular canal was found to increase with age, with the greatest distances observed in individuals over 50 years old. Similar trends were noted by Kovista et al.[37] in a study on the American population. These verdicts suggest that the craniofacial complex continues to change during the course of life, leading to variations in vertical dimension from the IAN, bone thickness, and anteroposterior distance[36]. Teeth can erupt and migrate slightly over time, particularly in response to occlusal forces and changes in dentition, affecting the proximity of tooth roots to the mandibular canal.

In current study, 92% of mandibular second molars exhibited root curvature, either mesially or distally. These findings closely mirrored those of Gambarini et al.[38] in the European population, where 85% of molars displayed similar root curvatures. Understanding the radius of these root curvatures is crucial for planning precise root canal instrumentation, effectively mitigating the challenges posed by anatomical variations.

### *Clinical Implications*

Root canal morphology exhibits variations influenced by the race and gender of patients. Understanding these ethnic differences allows clinicians to optimize treatment approaches. Cone-beam computed tomography, a three-dimensional, high-resolution imaging system, is invaluable for visualizing internal tooth anatomy and accurately measuring distances to the mandibular canal, which conventional radiography cannot achieve. For dental practitioners, understanding common anatomical variations such as the total number of root canals, incidence of additional roots, C-shaped canals, curvatures of the roots, and distances from the mandibular nerve canal in both genders is essential for successful endodontic treatment. This enhances treatment precision and improves overall treatment outcomes.

## *Conclusion*

In the observed sample, the study found that the mesial root of the mandibular second molar most frequently exhibited Vertucci's Type V canal configuration, followed by Type IV, while the distal root predominantly showed Type I. Additionally, C-shaped configuration with merged roots was found in 5.2% of scans observed. The distal root was closer to the canal than the mesial roots, and the average distances from the apices of the root to the canal were shorter in females than in males. Moreover, the distance from the root apex to the mandibular canal tended to increase with age.

This study provides insights into the anatomical variations of the mandibular second molar, which are critical for the success of endodontic treatments as root morphology can vary based on the patient's race and gender and also relevant in forensic contexts, different populations may exhibit variations in the morphology and number of root canals in teeth. These variations can be influenced by genetic factors, geographical ancestry, and environmental factors. Forensic odontologists can use these variations to help identify the likely ancestry or geographic origin of an individual based on dental remains. By understanding these ethnic variations, clinicians can optimize treatment strategies for better patient outcomes.

### *Ethical Approval*

This study was approved by the Ethics Committee, IECVDC/23/PG01/OMR/IVT/69, and the scans were gathered from patients who visited Vishnu Dental College and Hospital Bhimavaram, from March 2022 to February 2023.

### *Conflict of Interest*

The authors of the study declared no conflicts of interest in publishing the research work.

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Nil

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