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Root Canal Morphological Variations of Permanent Mandibular Second Molars Among Patients Reporting to Private Clinics in Vellore District, South India" – An In Vitro Cone Beam Computed Tomography Study.

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Introduction

A sound knowledge of root canal anatomy and its variations is essential for treatment planning and executing root canal procedures[1, 2]. It helps to reduce the chances of missed canals and procedural errors thus increasing the success rates[3]. The Mandibular molars pose challenges to Endodontist owing to its anatomic variations. They usually have two roots & three canals. Few common variations include combinations of one or two roots with one, two, three or even four canals and the C-shaped canals[4, 5, 6, 7.]

The developments in imaging modalities such as CT, MRI, nuclear medicine and ultrasonography not only revolutionized medical and dental diagnosis but also led to a shift in the diagnosis that was dependent upon static projection images to the digital 3-dimensional and interactive imaging. This is attributed to CT technology known as cone-beam Computerised Tomography. The original CT technology is used extensively in medical diagnosis and is designated as medical CT and the newer modality used primarily in dentistry is Cone beam computed tomography (CBCT) and also termed as cone beam volumetric tomography(CBVT), dental volumetric tomography, cone beam volumetric imaging,(CBVI) or dental computed tomography. [8, 9, 10, 11.]

Cone beam technology is medical image acquisition technique that uses a cone shaped beam of radiation centred on a two –dimensional detector. The source detector system performs one rotation around the object producing a series of 2-D images. During the exposure sequence, hundreds of plannar projection images are acquired in the field of view (FOV). Each pixel in 3D picture is called voxels. The images are reconstructed in a 3-D data set using a modification of the original cone beam algorithm developed by Feldkemp et al in 1984.In addition to increased accuracy and higher resolution, CBCT offers significant scan- time reduction and reduced cost for the patient. [12,13] In Endodontics CBCT plays a wide role from diagnosis of pulp and periodontal pathology, identification of missed, accessory canals, internal and external root resorption, vertical root fracture and elucidation of the cause of non-healing endodontically treated teeth.[14,15]

Although numerous research papers have evaluated the prevalence of variations of root canal anatomy of Mandibular Second molar, minimal research data was available amongst South Indian population. Hence, the purpose of this study was to investigate the variations in root canal anatomy of South Indian population using CBCT.

Hence the aim of this study was to investigate the root canal anatomy of permanent mandibular second molar in South Indian population using Cone Beam Computed Tomography to identify the number of roots & root canals, C-shaped canals, lateral canals, level of bifurcation and convergence along with the apical foramen exit which would be an eye opener for future generation.

Materials & Methodology

The study was approved by Institutional Review Board on 8/12/2015 with the QR CODE [IGIDSIRB2015NDP12PGPRCDE] and Institutional Ethical Committee at Indira Gandhi Institute of Dental Sciences [IGIDSIEC2016NDP12PGPRCDE] on 29/01/2016. This study was an observational invitro study and a multicentric study.

The extracted human carious and non carious mandibular second molars were collected from various private clinics in Vellore district, Tamilnadu, India. Patient consent form has been obtained prior to extraction. Inclusion criteria were non carious tooth extracted due to periodontal pathologies such as aggressive Periodontitis, juvenile periodontitis which are highly destructive form of periodontal disease occurring in healthy patients whose clinical features include rapid loss of periodontium and supporting structures that leads to mobility of teeth. Conditions involving extraction of deep cavitated carious teeth in patients of 40 – 60 years of both male and female , whom presumably not willing for endodontic therapy**.** Teeth excluded in the study are pathological and physiological conditions such as root fracture, root caries ,incompletely formed roots [open apex] respectively and restored teeth with silver amalgam, light cure composite resin restoration owing to possibility of generation of artifacts during CBCT.

The sample size was calculated using a Formula is **4pq/d*d [** p = proportion of population with bilateral c shaped roots (0.33), q = 1-p (0.67), d = absolute precision (0.05)]. Prevalence of subjects with bilateral C-shaped roots = 0.33 **Kim SY et al[43].**

Freshly extracted teeth were washed under running tap water immediately and stored in formalin10 %. All the collected samples fulfilled the inclusion & Exclusion criteria. Selected samples [n= 354] were then cleaned of residual soft tissues, bone fragments, stains and calculus using ultrasonic scaler.(CE approved Woodpecker Dental Ultrasonic Scaler UDS- P, Guilin Woodpecker Medical Instrument Co. Ltd., China.). Selected samples were examined visually and categorized based on the number of roots.

Four selected samples were mounted in a modeling wax block (Jig) vertically at the level of cementoenamel junction and scanned by a CBCT scanner (3D Imaging / CS 9300,Carestream Health, New York, USA) Aarthi Scan Center , Vadapalani and Baba Scan Center , Mylapore, Chennai, Tamil Nadu, India` The values were tabulated using 3D Care stream version1.8. Software. The 3-dimensional resolution or isotropic Voxel size was

90µmx90µmx90µmm with Spherical imaging volume of 5x5, real time image no magnification and reconstruction time is 2 minutes. The scan setting is 84 kVp5mA. The exposure time is 19.96 sec. Total radiation exposure 596mGy.cm^{2}.The software was also used in rendering the three-dimensional images through selective integration and measurement of adjacent voxels (all voxels are isotropic) in the display. (Objects within the volume are accurately measured in different direction). The images generated by CBCT system are processed and all the parameters were recorded.

Incidence of C-shaped canal in mandibular second molars were classified based on modified Melton's Classification**.** In Melton's classification, there has been no clear description of the difference between categories II and III (i.e. C2 and C3, respectively) and clinical significance, hence modified Melton's classification was used. Incidence of roots and root canal morphology were classified based on Weine's classification. Similarly isthmus configuration, level of bifurcation or convergence - Apical, middle and coronal were also analysed.

Keywords: Cone beam computed tomography,Mandibular second molars,C- shaped canals, Root canal,Bifurcation

Results

According to the present study, the incidence of C-shaped canal in Vellore district , South Indian population as classified by modified Meltons classification was found to be 8.4% and 6.2% showed fused root. This incidence correlates with the study conducted by Neelakandan et al[35] (2010). Based on Vertucci classification , the present study showed the incidence of two rooted second mandibular molar to be 98%. On further classification of root morphology based on Vertucci classification ,mesial roots showed an incidence of 27% for type 3 canals , 25% for type 2 canals , 20 % for type1 canals, 11% for type 4 canals ,9% for type 6 canals , 5.1% for type 5 canals, 1 % for type 7 canals whereas in distal roots showed the incidence is 75% for type 1canals ,8 % for type 2&3 canals , 2% for type 4 & 5canals and 1 % for type 6 & 7 canals. Also the study revealed two rooted second mandibular molar of mesial root 97.2% and distal root was 98.8%. isthmus configuration reveled for mesial root Type 3-26.5% ,Type 5- 24.5%,Type1-20.6%,Type4-0.8%,Type 2-0.5% and for the distal root Type 1-33.8%,Type3-27.9%,Type 5-2.8%,Type 2-1.6%,type 4-0.5%. Level of bifurcation was found at coronal -4.5%,middle -22.5%,apical -64.1% in mandibular second molars.

Table 1: Incidence of c shaped canals (n= 354)

Incidence of C-shaped canals	Frequency Percentage	95% Confidence Interval
	8.4%	5.5-11.3%

Table 2: C-Shaped canals

Type of C-shaped Canals	Frequency Percentage	95% Confidence Interval
Class 1	2.5%	0.9-4.1
Class 2	3.3%	1.4-5.2
Class 3a	0.2%	-0.3-0.7
Class 3b	1.9%	0.05-3.3%
Class 4	0.5%	-0.2-1.2%

Table 3: Vertucci Classification - Mesial root

Vertucci	Frequency Percentage	95% Confidence Interval
Type 1	20%	15.8-24.2%
Type 2	25%	20.5-29.5%
Type 3	27%	22.4-31.6%
Type 4	11%	7.7-14.3%

Type 5	5.1%	2.8-7.4%
Type 6	9%	6-12%
Type 7	1%	0-2 %
Type 8	0%	0%

Table 4: Vertucci Distal root

Vertucci classification	Frequency Percentage	95% Confidence Interval
Type 1	75%	70.5-795%
Type 2	8%	5.2-10.8%
Type 3	8%	5.2-10.8%
Type 4	2%	0.5-3.5%
Type 5	2%	0.5-3.5%
Type 6	1%	0-2%
Type 7	1%	0-2%
Type 8	0%	0%

Table 5: Incidence of two rooted 2nd mandibular molar (N=354)

Incidence of two rooted 2nd mandibular molar	Frequency Percentage	95% Confidence Interval
	98%	96.5-99.5%

Table 6: Incidence of two rooted 2nd mandibular molar root canals (N=354)

Incidence of two rooted 2nd mandibular molar root canals	Frequency Percentage		95% Confidence Interval	
	Mesial	Distal	Mesial	Distal
	97.2%	98.8%	96.5-99.5%	97.7-99.9%

Table 7: Level of bifurcation

Level of bifurcation	Frequency Percentage	95% Confidence Interval
Coronal	4.5%	2.3-6.7
Middle	22.5%	18.2-26.8%
Apical	64.1%	59.1-69.1%

Table 8: Isthmus configuration Mesial

Isthmus configuration	Frequency Percentage	95% Confidence Interval
Type 1	20.6%	16.4-24.8%
Type 2	0.5%	-0.2-1.2%
Type 3	26.5%	21.9-31.1%
Type 4	0.8%	-0.1-0.7%
Type 5	24.5%	20-25%

Table 9: Isthmus configuration Distal

Isthmus configuration	Frequency Percentage	95% Confidence Interval
Type 1	33.8%	28.9-38.7%
Type 2	1.6%	0.3-29%
Type 3	27.9%	23.2-32.6%
Type 4	0.5%	-0.2-1.2%
Type 5	2.8%	1.1-4.5%

Discussion

The clinician should have sound knowledge of the internal anatomy of different teeth which forms the corner stone for successful prognosis of root canal therapy. Moreover, he should be familiar not only with normal morphology and dimensions of root canal but also the abnormal ones too to expect the unpredictability. A number of factors contribute to variations in root and root canal morphology including ethnic background, gender, and age of the studied population.

Many techniques have been used to investigate the internal anatomy of the teeth in the endodontic literature to evaluate root canal configuration such as root sectioning, Canal remodeling, canal staining and clearing, radiographic techniques such as, periapical radiographs, Micro CT, Spiral CT, & CBCT.

The literature reports that histological sections and a polyester cast resin technique to examine the canal morphology of C-shaped canals in extracted mandibular second molars. Histological sections were made at only one thin section from each cervical, middle, and apical third of roots and polyester resin casts were fabricated in teeth. Although the complete complexity of the root canal morphology can be visualized as 3D by using the resin cast, the main disadvantages are that resin may not fill canal the entire root canal systems or it might tear in thin areas.

Many investigators used the clearing technique for the in vitro 3D evaluation of root canal systems. However this technique is invasive and also requires lot of preparation of tooth hence technique sensitive.

Radiographs are non-invasive method for the study of root canal anatomy. However, periapical radiograph are taken in the buccal–lingual direction and provides only 2D information about 3D teeth. Other radiographic techniques such as micro CT, spiral CT and CBCT provide a 3 dimensional view of the canal anatomy. Nance et al reported that the spiral CT scan enabled a statistically significant increase in canal detection as compared with conventional radiography. The literature reports that spiral CT to evaluate C-shaped canals of single rooted mandibular second molars due to technical advantages since CT images were obtained one slice at a time. C-shaped canals were found in over one third of single rooted mandibular second molar teeth (35.7%) by spiral CT technique. But demerits of spiral CT are increased image noise which necessitates continuous scanning, volume averaging artifacts and additional processing time. Apart from these, only single tooth can be evaluated at a time.

The micro-CT is an excellent tool for experimental endodontology as it can produce detailed informative images of the anatomy of teeth. It is useful for researchers who desire to study dental anatomy in detail and to investigate the effect of procedures on the endodontic space. However micro CT requires lot of radiation and time for completing the scan for single tooth[47].

Cone beam computed tomography (CBCT) can provide 3D images within a short span of time and radiation. It also allows multiple teeth to be scanned. CBCT is an ideal tool for studies on incidence of canal morphology as it requires a larger sample size. Evidence in literature states that CBCT scanning was as accurate as the modified canal staining and clearing technique in identifying canal anatomy. The differences between the results obtained by the evaluators were not significantly different when endodontists were compared with radiologists also while analysing the CT images, radiologists could interpret the number of root canals better than endodontist evaluators. The endodontic evaluators and radiologists identified 98% to 100% of root canals as compared with modified canal staining and clearing method when CBCT. The slice thickness for CBCT ranges from 80 to 200 m. The primary advantages of CBCT are significantly lower effective radiation dose, short exposure time (2-5 seconds), less expensive than conventional CT scanning, and highly accurate. Also, CBCT measurements are geometrically accurate because of the fact that the CBCT voxels (3D pixels containing data) are isotropic. Since this provides an excellent way to obtain information on root canal anatomy, current study uses CBCT as it has demonstrated to be a possible method for assessment of teeth with unusual anatomy. It is a 3-dimensional in vivo technique, it is useful for prevalence studies and also it avoids confounding factors in ex vivo studies. In the present study, a voxel size limit of 90 µmx90µmx90 µm was established, considering this measure proved to be successful on detecting C-shaped morphologies as per previous studies. This resolution enables us to study the root canal morphology especially c shaped canal morphology and also allows the volume calculations.

According to the present study, the incidence of C-shaped canal was found to be 8.4% and 6.2% showed the fused root which correlates with the study done by Neelakandan et al[37] (2010). C-shaped canal configuration has been shown to have a high prevalence (14%-52%) in the mandibular second molars of Chinese, Japanese, and Lebanese populations. C-shaped canal morphology was noted in 7.5% of the teeth examined, which was similar to the prevalence in the Mongoloid group (10%) but much less than reported in the Burmese (22.4%) populations. Investigation showed that 38.4% of the C-shaped roots (10specimens) had a single canal, which was similar to the observation made in Thai population but higher than in Burmese molars.

C-shaped root canal system is the morphology of its horizontal cross section is in the form of a C, with canals which may or may not be separate,mostly seen in mandibular second molars, although it occurs in maxillary and other mandibular molars. When examining the floor of the pulp chamber of lower molars displaying this atypical configuration, normally the entrance of the canal is observed as a C-shaped orifice (an arc of 180º), in the form of a band, or a deep semilunar groove connecting the distal, mesiobuccal and mesiolingual canals. The concavity of the C may be oriented buccally or lingually. In other cases the orifice may take the form of an incomplete C, with union of the distal and mesiobuccal canals, and the presence of an isolated mesiolingual canal, giving the canals the appearance of a semicolon. It may also present as a C-shaped canal with union of the distal and mesiolingual canals with a separate mesiobuccal canal. The prevalence of C-shaped canal system in second mandibular molars has been reported to be 31.5% for the Chinese population, which is much higher than that reported for other populations.Irregular areas in a C-shaped root canal system houses soft tissue remnants or infected debris which may escape thorough cleaning or filling. Manning suggested that the failure of the Hertwig's epithelial root sheath to fuse on the lingual or buccal root surface was the main cause of a C-shaped root, which always contains a C-shaped canal. The C-shaped root may also be formed by coalescence because of deposition of cementum with time. C-shaped roots showed wide variations in canal configuration (types I, III, IV, V, VII, 4-2, and 2-3) in accordance with other reports. Most of the C-shaped roots (57.6%) showed two separate apical foramina, which was in contrast to the findings [26]. The most commonly observed morphology in the study population was the two-rooted morphology, with type IV canals and type I canal systems predominating in the mesial and distal roots, respectively (Mongoloid trait).

Evidence in literature describes various trends in the shape and number of roots and root canals among different human races. This variation appears to be genetically determined and may be used in tracing the ethnic origin of the subjects. According to the present study the incidence of two rooted second mandibular molar was found to be 98%. On further classification of root morphology based on Vertucci classification, mesial roots showed an incidence of 27% for type 3canals , 25% for type 2 canals , 20 %for type1 canals, 11% for type 4 canals ,9% for type 6 canals , 5.1% for type 5 canals, 1 % for type 7 canals whereas in distal roots showed the incidence is 75% for type 1canals ,8 % for type 2&3 canals, 2% for type 4 & 5canals and 1 % for type 6 & 7 canals. According to the present study 98.8%for two rooted mandibular second molar and for mesial aspect %and for the distal root 98.8%. The most common morphology was two separate roots (83.4%).

Root canal isthmus, a narrow ribbon-shaped communication between two root canals is an important anatomical feature as it contains pulp remnants, necrotic tissues, micro-organisms and their byproducts. An isthmus also called as corridor, a lateral interconnection, a transverse anastomosis has the prevalence which varies according to the tooth type, root levels and age. An isthmus might be found in roots with C-shaped canals or in two adjacent canals such as mesial roots of mandibular molars, premolars, and so on. Isthumus is also classified as complete or partial, a continuous connection between two main canals is considered as complete isthumus and an incomplete communication with one or more openings is an partial isthumus. Hence any root possessing a compressed form with more than one canal has the potential to contain isthumus[48].The mesial root of the mandibular first molar exhibits the most number of isthmuses. The majority of isthmuses have been reported in the apical 5 mm of root canals. A study in a Chinese population reported that the prevalence of isthmuses decreases with age in molars due to the deposition of secondary dentin[49].

One of the most difficult clinical challenges faced by the operator is the cleaning and disinfection of root canal intercommunications and isthmuses. Because mechanical instrumentation is not feasible, efforts should concentrate on efficient delivery and activation of irrigants to achieve proper disinfection. Failure to access, debride, and disinfect this complex anatomy might have a direct effect on the treatment outcome[31].

Isthmuses are very common in the mesial roots of mandibular permanent molars in the Iranian population, with the highest prevalence at 6 mm distance from the root apex. Therefore, endodontic microscopes and newer technologies should be used for cleaning and obturation of isthmuses to achieve higher success rates in endodontic treatment[31]. incidences of canal isthmuses in mandibular first molars range from 54 to 89% in the mesial root, and from 15 to 17% in the distal root, also different sections show the highest incidences 4–6 mm from the apex[42]. Incidence for Isthmus configuration of mesial root found for type 3-26.5%,for type 5- 24%,for type 1-20.6%,for type 4-0.8%,and for type 2 -0,5%,and for distal root found for type 1-33.8%,for type 3-27.9%,for type5-2.8%,for type 2-1.6%and for type 4-0.5%.

The level of bifurcation and convergence of root canals in the mesial and distal roots of the mandibular first molar may vary in different populations. Therefore, it is important to investigate these aspects in other populations' too[31]. Present study revealed that out of 354 specimens, level of bifurcation at coronal third to be 4.5% while that of middle third was 22.6% and apical third was 64.1% respectively. Canal bifurcation was observed in the apical 4mm with majority occurring within 2 mm from the apex in 17 out of 58 teeth as observed by Fan in 2004[27]. Also morphometric assessments in literature shows that, the bifurcation was located apical on the lingual than the buccal surface in mandibular molars. Periapical radiographs have less diagnostic accuracy, for initial buccal involvement hence CBCT is the valuable tool for identification[50].

Conclusion

The most common morphology in Indian mandibular second molars was the two-rooted teeth with three canals (two mesial and one distal). C-shaped canals were found in 8.4% of the teeth, in that C2 canal were found to be the most at 3.3% the canal shape resembled a semicolon resulting from the discontinuation of the “C” outline, but either angle " or # should be no less than 60°. The observations made in this study show that mandibular second molars among patients reported to private clinics in Vellore District, South India exhibited both Mongoloid and Caucasian traits.

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