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RESEARCH ARTICLE

STUDY OF ROOT CANAL ANATOMY IN HUMAN PERMANENT TEETH IN A SUBPOPULATION OF SOUTH INDIA REGION USING CONE BEAM COMPUTED TOMOGRAPHY

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Glossary of abbreviations
CBCT-Cone Beam Computed Tomograph
CCD-Charged Couple Device
DB- Disto-buccal
MB- Mesio-buccal
PSP-Photo phosphor plates

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ABSTRACT

Introduction and Objectives*:* To evaluate the diversity of root canal morphology in human permanent teeth in a subpopulation of South India by using CBCT images. ***Materials and methodology****:* CBCT images of 520 teeth (100 patients, mean age of 42 years) from database were used. All teeth were evaluated by preview of the planes - sagittal, axial, and coronal. ***Results:*** Single rooted maxillary central incisors (100%), lateral incisors (98.5%) and canines (94.5%) commonly showed type I configuration. Maxillary first premolars displayed two roots in 78.4% and one root in 21.6% respectively. Maxillary second premolars displayed two roots in 10.8%and one root in 89.2%.Predominately maxillary molars were 3 rooted. Mesiobuccal root (MB) of maxillary first molars showed most common configurations of type I in 64% and type IV in32% of the teeth. Maxillary second molars reported with three roots in 81.2%, two roots in 14.1%and one root in 4.7% of the teeth. Type I (76.5%) was the most common configuration observed followed by type IV of 14% in maxillary second molars. Mandibular incisors and canines presented type I configuration in 84.4%, 93.4% respectively. Mandibular premolars had single root with frequencies of type I in 79.4% and type V in 5.8%. Mandibular first molars possess variations of type IV in 62.43% followed by type II in 33.7% in their mesial roots. The frequency of Radix Endomolaris was of 23.1%. Mandibular second molar mesial roots displayed 55.3% of type IV, 41.3% of type II and 3.4% of type III. The prevalence of C-shaped canals in mandibular second molars was found to be 9%. ***Conclusion:*** Prevalence of Radix Endomolaris in mandibular first molars was of 23.1%. Single rooted second mandibular molars showed 9% frequency of having "C" shaped configuration and type III of 6.06% was reported in this study. Such variations should be taken into consideration and knowledge of canal anatomy would eventually help the operator to deliver a better quality of endodontic therapy. CBCT with its high resolution and magnification properties, enables better identification of canal anatomy and its variations.

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INTRODUCTION

The success of endodontic therapy hinge on the access cavity preparation, quality of root canal preparation, three-dimensional obturation and coronal restoration. Proper cleaning and shaping of the root canal system always stood as the primary goals of the endodontic treatment. The internal anatomic complexities are often masked by the external surfaces, which gives an impression of relatively simple and uniform anatomy, leading to misdiagnosis. False assumptions can be made about the root canal anatomy of teeth which may lead to missing of canals, improper debridement and breakage of root canal instruments during treatment. It has therefore of utmost importance that the clinician must have a thorough knowledge of root canal morphology and its possible variations to achieve a high level of success. Micromorphology of the tooth constitutes the anatomic structures like number of roots, root canals, apical foramina, root canal isthmuses, root ramifications, root curvatures, developmental disturbances (Estrela *et al.,* 2015). There are different in-vitro, ex-vivo and in-vivo methods to study tooth micro morphology like decalcification, clearing, radiopaque gel infusion, cross-sectional cutting, histological evaluation, radiography, stereomicroscopy analysis, and macros copy evaluations. Advanced methods available are Digital radiography, Scanning Electronic Microscopy, and Computed Tomographic techniques (Datta *et al.,* 2015). Radiographic evaluation of root canals is the most common methods employed for evaluating the root canal morphology. For this purpose various radiographic modalities are available. Among these Cone beam computed tomography (CBCT) provides dentists high-quality 3-dimensional images of dental structures owing to its high spatial resolution. Unlike the conventional CT scans, CBCT has reduced acquisition time and irradiation dose. Michetti *et al.* compared the validation of CBCT and histological sections

and found a strong correlation between them in exploring the canal anatomy (Michetti *et al.,* 2010). Evaluation of CBCT images always resulted in a greater number of root canal systems identification than evaluations of Digital radiography using PSP or CCD images (Matherne *et al.,* 2008). Kajana *et al*. (2018) compared the accuracy of CBCT in revealing the number and form of the root canals of different maxillary and mandibular teeth with clearing and staining method and reported strong correlation between them. CBCT is therefore recommended for improving the clinician's knowledge of the root canal morphology, which will undoubtedly result in more successful endodontic treatments (Kajana *et al*., 2018). Also the available literature supports that racial and genetic factors have their influences on the root canal morphology, thereby necessitating its knowledge among different races. The Indian population is generally considered to be an amalgamation of several ethnic groups with significant characteristics of Caucasian, Mongoloid, and Negroid races, which is generally referred to as the Dravidian group.[6]There were limited reports on the root canal morphology assessment using CBCT. Therefore, this study was designed to evaluate the diversity of root canal morphology in human permanent teeth in a subpopulation of South India by using CBCT images.

MATERIALS AND METHODS

A retrospective study was planned with CBCT images of 520 teeth of 100 patients with mean age of 42 years were taken from data base of Department of Radiology with time span of 16 months (March 2017 to June 2018). These scans were taken for different diagnostic purposes. Intact teeth with matured apex were included in the study. Teeth with endodontic treatment, with post or crowns, calcified canals, internal or external root resorptions, and those undergoing for orthodontic treatment, and with developmental disorders were excluded from the study. The scans were sourced from SCANORA 3D(SORDEX, Tuusula, Finland)CBCT machine thickness 0.100mm,FOV 61×41mm, Voxel 85 μm, Tube voltage was 90kVp, Tube current was 10ma, Exposure time was 6.1 sec with a scanning time of 10sec (608 projections).Images were examined using the ONDEMAND 3D software (Cybermed Inc.USA). The frequency of the number of roots, root canals, canal configuration and apical foramina in all teeth was evaluated by the previewing all the three planes i.e sagittal, axial, and coronal. Navigation followed the coronal to apical direction, as well as the apical to coronal direction in axial sections individually for each root .All CBCT images were assessed by two examiners (one Endodontist and one Radiologist) and concluded after discussing with a third examiner.

Each tooth was assessed for

1. Number of roots
2. Number of canals
3. Canal configuration according to Vertucci classification.
4. Descriptive statistics were presented by means of frequency distribution and cross-tabulation.

RESULTS

Number and morphology of roots: Maxillary central incisors displayed single root in 98.5% and two roots in 1.5% of the teeth. All maxillary laterals and canines had only one root. Maxillary first premolars displayed two roots in 78.4% and one root in 21.6% of the teeth. Maxillary second premolars displayed two roots in 10.8%and one root 89.2% of the teeth. Maxillary first molar reported the most common configuration of 3 roots in 96% and 2 roots in 4%.Second molars had three roots in 81.2%, two roots in 14.1%and one root in 4.7% of the teeth. All mandibular centrals, laterals and canines had one root. Mandibular first premolars had one root in 97% and two roots in a 3% frequencies. Mandibular second premolars had one root in 96.7% and two roots in a 3.3% frequencies. Mandibular first molars had two roots in 76.9% and three in 23.1% of teeth. Mandibular second molars had two roots in 84.9%, one root in 15.1%.

Number of canals and configuration: Maxillary centrals had one canal in 98.5% and 2 canals in 1.5% with type I canal configuration. Maxillary laterals had one canal and type I in 98.5% and type IV in 1.5%. Maxillary canines revealed predominately type I in 94.5% followed by frequency of 2.75% in both type III and type IV. Maxillary first premolars with two roots had displayed type I canal anatomy. Single-rooted premolar had 50% type II frequency followed by type I and type III. Second premolars with type I configuration was 82% followed by 9.8% intype II and 4.8% intype IV. In maxillary first molars with three roots, MB (Mesiobuccal root) showed different configurations. The most common was type I with 64% and type IV with 32%.Type I was predominantly observed in two rooted first molars. Three rooted Maxillary second molars showed type I of 76.5%, type II of 14.1%,type IV of 6.7% and type III of 2.7%.

Mandibular teeth: Mandibular central and lateral incisors had type I configuration in 84.4% followed by type II in 10.4%. In canines type I was the most common with 93.4%, other configurations observed were type II and III. Mandibular first premolars had single root with type I in 82.3%, type II in 8.8%, type V in 6%, and type III in 2.9% of the teeth. Second premolars showed predominately type I configuration. Mandibular first molars had the most common anatomy of 2 roots and mesial roots having 2 canals. The configurations of type IV in 62.5%, type II in 33.7% and type V in 3.8% were reported in mesial roots of first molars. Distal roots had type I in 67%, type II in 18%with some roots showing frequency of 7.5% in both type IV and V. Frequency of Radix Endomolaris was of 23.1%. Second molar mesial roots displayed 55.3% of type IV, 41.3% of type II and 3.4% of type III. Single-rooted mandibular second molars showed 9% frequency of having "C" shaped configuration and type III with 6.06%.

DISCUSSION

A successful endodontic treatment necessitates complete cleaning and sealing of the root canal system.[7]So having knowledge about the canal configuration of the teeth is mandatory for the clinician. Each patient must be judiciously analysed for the anatomic, ethnic and genetic features. However, the distribution and frequency of the number of roots, root canals and canal type in the studies of anatomy varies depending on the sample size, the methodology used, knowledge of the tooth age, and the aspects associated with ethnic factors of the population (Estrela *et al.,* 2015). Silva EJNL *et al.* (2013) analysed root canal morphology of mandibular molars by using CBCT and mentioned the diversity of ethnic community in Brazilian population, which derives of important genetic contributions from four continental

Table 1. Frequency of number of roots and canals in maxillary teeth (%)

Maxillary	Frequency of number of roots			Frequency of canals			
TOOTH	1	2	3	1	2	3	4
Central incisor	98.5	1.5		98.5	1.5		
Lateral incisor	100			98.5	1.5		
Canine	100			97.5	2.75		
First premolar	21.6	78.4		10.8	89.2		
Second premolar	89.2	10.8		75.1	24.9		
First molar		4	96		4	64	32
Second molar	4.7	14.1	81.2		18.8	76.5	4.7

Table 2. Frequency of number of roots and canals in mandibular teeth (%)

Mandibular	Frequency of number of roots			Frequency of canals			
TOOTH	1	2	3	1	2	3	4
Central incisor	100			84.4	15.6		
Lateral incisor	100			84.4	15.6		
Canine	100			96.7	3.3		
First premolar	97	3		88.2	11.8		
Second premolar	96.7	3.3		96.7	3.3		
First molar		76.9	23.1		6.6	63.7	29.7
Second molar	15.1	84.9		9	18.1	72.9	

Table 3. Canal configuration of maxillary teeth

Maxillary Tooth	Root	Type I	II	III	IV	V	VI	VII	VIII	IX	Additional
Central		100									
Lateral		98.5			1.5						
Canine		94.5		2.75	2.755						
First premolar	Single	79.4	10	4		6.6					
	Two	100									
Second premolar		82	9.8	3.4	4.8						
First Molar	MB	64	4		32						
	DB/ P	100									
Second Molar	MB	76.5	14.1	2.7	6.7						
	DB/ P	100									

Table 4. Canal configuration of mandibular teeth

Mandibular Tooth	Root	Type I	II	III	IV	V	VI	VII	VIII	IX	Additional
Central		84.4	10.4	5.2							
Lateral		84.4	10.4		5.2						
Canine		93.4	3.3	3.3							
First premolar		82.3	8.8	2.9		6					
Second premolar		100									
First Molar	M	67	33.7		62.5	3.8					
	D		18		7.5	7.5					
Second Molar	M	96.3	41.3	3.4	55.3						
	D		0.7	3							
Second molar	Single			6.06							9 “C’ shape

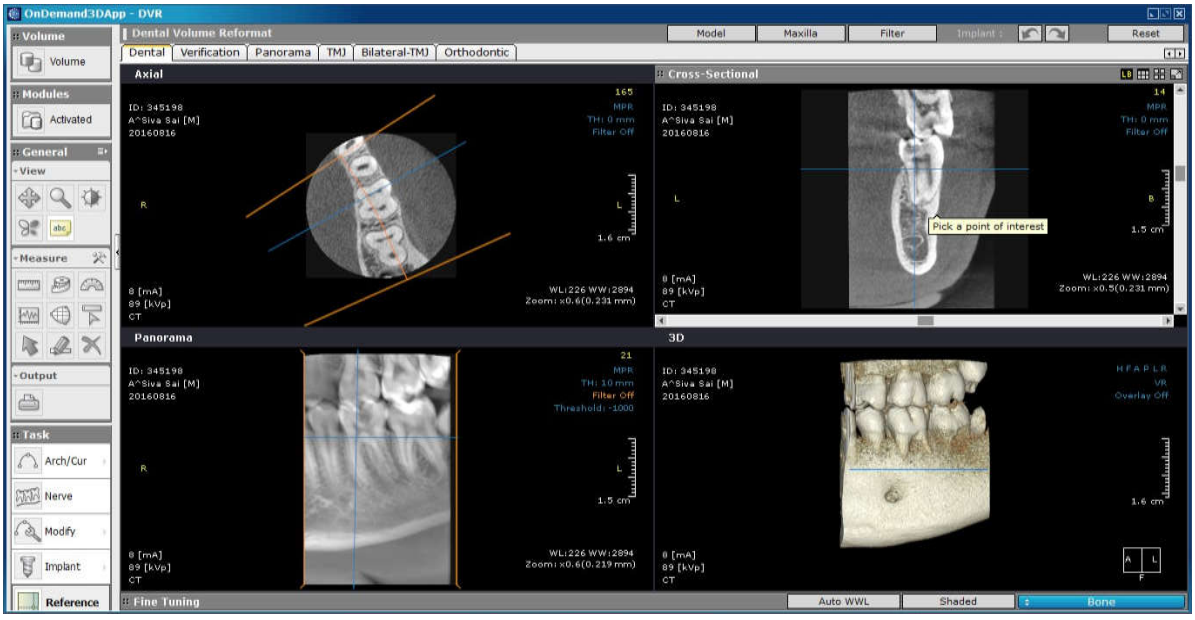

Fig. 1. DICOM images are displayed in 3 orthogonal planes (sagittal, axial, and coronal) and further reconstructed in 3D volumetric set

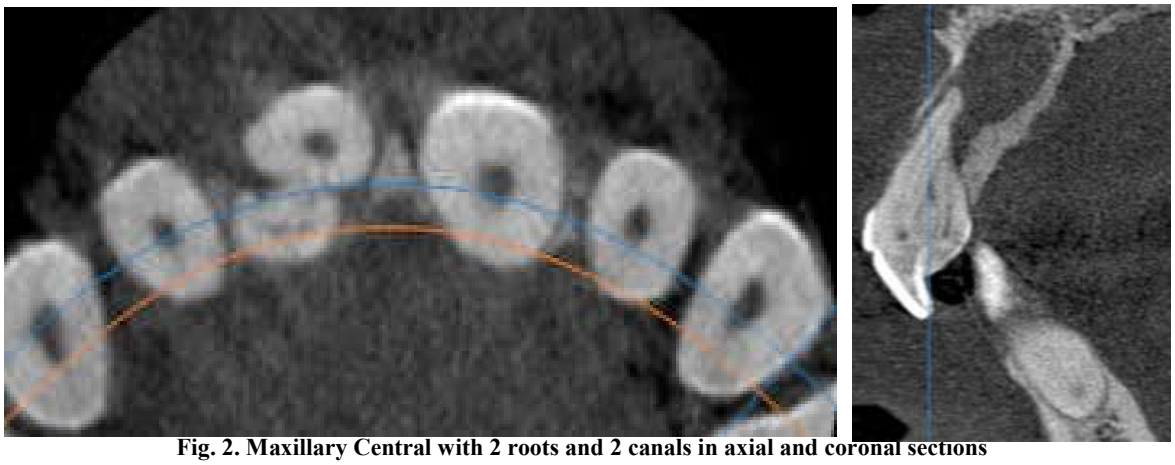

Fig. 2. Maxillary Central with 2 roots and 2 canals in axial and coronal sections

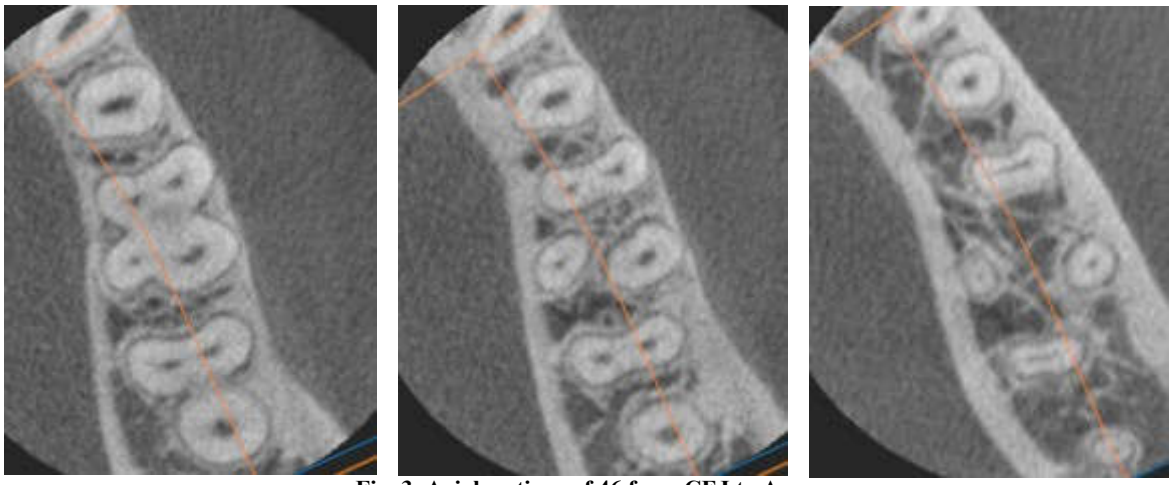

Fig. 3. Axial sections of 46 from CEJ to Apex

Fig. 4. C shaped in axial section of second molar

accordance with the study conducted by Jain *et al.* (2017). Maxillary first premolars reported with two roots and type I canal anatomy. Second premolars with type I 82% followed by type II, IV configurations. These results were consistent with studies conducted by Atieh (2008) and Monsarrat *et al.* (2016). In maxillary first molars, Mesio-buccal root (MB) showed different configurations and the most common was type I (64%) followed by type IV (32%). Three rooted Maxillary second molars commonly showed type I (76.5%), type II of 14.1% and type IV of 6.7%.Maxillary second molars with two roots showed type I and molars with one root showed type IV configuration predominately. Distal and palatal roots showed type I configuration. These observations were in agreement with various studies done on the Indian population, which showed that the MB roots of both first and second molars exhibited a wide variation of canal anatomy (Neelakantan *et al.,* 2010; m Singh *et al.,* 1994).

Such variation have been reported by Alavi *et al.* (2002) in Thai molars. In present study none of the maxillary molars showed fused roots or C-shaped canals, in contrast to reports on the teeth of Caucasians (Thomas *et al.,* 1993). Mandibular central and lateral incisors had type I configuration in 84.4% followed by type II in 10.4%. In canines type I was the most common with 93.4%, other configurations observed were type II and III. Higher prevalence of the second canal presence was reported in the incisors than in canines. Rahimi *et al.* (2013) study reported that the incisors had one root, and a relatively high percentage of two-rooted mandibular canines in North-West Iran population which was contrast to present study; all mandibular anterior's were single rooted (Rahimi *et al.,* 2013). In present study, Mandibular first premolars had single root with type I in 82.3%, type II in 8.8% and type V in 6%.All second premolars showed type I configuration. These findings were similar to a study of Gender difference and root canal

morphology in mandibular root and canal morphology of mandibular premolars in a Spanish population. They also reported that Vertucci configuration types I and V were the most prevalent. The first premolars showed significantly greater variability than the second premolars (Llena *et al.,* 2014). In present study, Mandibular first molars had two roots in 76.9%, three in 23.1% frequency. Mandibular second molars had two roots in 84.9% and one in 15.1%. Mesial root of first molar had variations of type IV of 62.5% followed by 33.7% of type IIand 3.8% oftype V. Distal roots displayed type I in67% and type II in 18%. Walker RT et al. reported only 15% of the mandibular first molars were found to be 3 rooted (Walker, 1988). Akhlaghi *et al.* (2017) study in Iranian population reported that all the teeth (100%) had two canals in the mesial root, while 61.3% of the samples had one distal root canal. In doubled-canalled distal roots, 68.8% and 24.3% were type II and type IV, respectively .The notable prevalence of type IV configuration was found in both roots of mandibular first molars. Chourasia *et al.* (2012) concluded that, two and three roots were present in 96.7% and 33% of the mandibular first molar teeth, respectively (Chourasia *et al.,* 2012). Qudah and Awawdeh conducted a similar study on Jordanian population and reported the majority of mandibular first molars had three (48%) or four (46%) canals, whilst 4% had a third disto-lingual root. Common configuration in the mesial root was type IV (53%) and in distal root was type I (54%) (Al-Qudah *et al.,* 2009). Two-rooted second molars; type IV in mesial root accounts for 55.3%, type II for 41.3%. Single rooted molars showed 9% frequency of having "C" canal configuration and type III of 6.06% was reported in the present study. In a study on Belgian and Chilean population it was reported that the mesial root of the mandibular second molars have types III and V as the most frequent configurations. Type I was the most common configuration in the distal root .The prevalence of C-shaped canals was less than 10% in both Belgian and Chilean population (Torres *et al.,* 2015) and about 41.27% in Chinese population (Wang *et al.,* 2012). Incidence of "C" shaped canals were consistent with a study on population of central India (9.7%) (Wadhwani *et al.,* 2017).

Conclusion

Prevalence of Radix Endomolaris in mandibular first molars was of 23.1%. Single rooted second mandibular molars having "C"shaped canals showed 9% frequency. Owing to this there is an every possible chance of genetic and racial factors influencing the micromorphology of root canal system. Precise understanding of the multifaceted root canal anatomy of Indian population would eventually help the operator to perform and deliver a better quality of endodontic therapy with high success rates.

Conflicts of interest-None
Acknowledgment- None

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