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Biometric Analysis of C-shaped Root Canals in Mandibular Second Molars Using Cone-Beam Computed Tomography

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ABSTRACT

Introduction: The configuration of C-shaped root canals, root canal wall thickness and orientation of the thinnest area using CBCT in mandibular second molars were assessed. **Methods and Materials:** Seventy five CBCT scans were evaluated. Axial sections were evaluated to determine the configuration of C-shaped canals in the coronal, middle and apical regions. The root canal path from the orifice to the apex, the thinnest root canal wall and its orientation were all determined. Data were analyzed using one-way ANOVA and post hoc Tukey's test. **Results:** The most common configurations were Melton's type I in the coronal and middle and types I and IV in the apical region. The mean thicknesses of the thinnest root canal wall were 1.94±0.43, 1.42±0.57 and 1.10±0.52 mm in the coronal, middle and apical regions, respectively. The lingual wall was the thinnest wall in the coronal, middle and apical regions and it was thinner in the apical than in the middle and coronal regions. The lingual wall was thinner in the middle third of the mesial root compared to the distal root ($P<0.05$). **Conclusion**: The lingual wall was the thinnest in C-shaped root canals of mandibular second molars of an Iranian population. Type, number and pathway of canals may vary from the orifice to the apex.

Keywords: Biometric Identification; C-shape Root Canal; Cone-Beam Computed Tomography

Introduction

Missed or untreated canals are common causes of endodontic failure. Adequate knowledge of root canal morphology and its variations among different races and ethnicities is helpful for increasing the success of endodontic treatment [1].

C-shaped root configuration in mandibular second molars is a morphological variant, first described by Cooke and Cox [2]. The most common cause of C-shaped root canals is the failure of Hertwig's epithelial root sheath to fuse in the buccal or lingual root surface [3]. In C-shaped root canals, the orifice(s) in the floor of the pulp chamber are in the form of the English letter C. It starts from the mesiolingual aspect of the pulp chamber, goes around the buccal tooth surface and terminates at the distal aspect of the pulpal floor. The morphology of these canals changes along the root canal. Thus, the real anatomy of the root canal system cannot be determined by the appearance of the orifice(s) [4]. Root and canal morphology of the mandibular molars were previously evaluated in selected Iranian populations by CBCT and transparency method and it was reported to be between 7.2% [5], 17.6% [6], and 21.4% [7]. The highest prevalence of C-shaped root canal system has been reported to be in the mandibular second molars [2, 4, 8, 9]. The prevalence of root fusion [10, 11] are C-shaped canals is higher in Asian populations (up to 44.5%) [12-17] while it is as low as 2.7% in Americans [18]. Therefore, assessing the prevalence of this form of root canal morphology is helpful in enhancing the success of root canal treatment.

A C-shaped root canal system should meet all the four following criteria [4]: Fused roots, a longitudinal groove on the buccal or lingual root surface, at least one axial section of root canal showing C-shaped morphology and roots fused together in their entire length.

Various methods have been used to study the root canal morphology including tooth staining and clearing [19], radiography [20], contrast media radiography [21] and computed tomography (CT) [22]. Conventional radiography has several limitations for evaluating endodontic complications mainly due to the superimposition of the structures [23].

Cone-beam computed tomography (CBCT) is successfully used in clinical dentistry for implant placement, measurement of buccolingual and mesiodistal widths of teeth, detection of the type of root canal filling material, metal posts, caries, assessment of the position of roots relative to the maxillary sinus and elimination of the superimposition of the structures. CBCT can be used for evaluating the canal wall thickness [24] and detecting root canal configurations which can be helpful for endodontic treatment of teeth with complex root canal morphologies [25].

The aim of this study was to assess the configuration of C-shaped root canals, root canal wall thickness and orientation of the thinnest area using CBCT in mandibular second molars.

Materials and Methods

This study was conducted on an Iranian sub-population residing in Shiraz, Iran. The subjects were selected from patients above 15 years of age, presenting to the oral and maxillofacial radiology clinics of Shiraz to obtain CBCT scans for different dental treatments, using convenience sampling. The CBCT of patients had to include an artifact-free, high-resolution, clear image of mandibular second molars. Scans showing endodontically treated or open-apex mandibular second molars or signs of root resorption or calcification were excluded. Of 550 CBCT scans, 75 CBCT scans showing mandibular second molars with C-shaped root canals were eventually recruited.

Three-dimensional scans of the teeth were obtained in axial, coronal and sagittal sections using Planmeca ProMax 3.2.O.R 3D imaging unit (Serial number kpp4001179, 3D mid, Helsinki, Finland) and evaluated in DICOM format using Planmeca/Romexis software. The exposure settings were 90 kVp, 14 mA, 15 sec, 15-bit gray scale and 10×10×10 cm field of view (maximum settings). CCD detector with 1024×1024 matrix and a 0.15-mm voxel size was used.

Table 1. Canal wall thickness in the apical zone of the C-shaped canal

Type of C-shaped (N)	Distal			Mesial			Lingual			Buccal		
	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max
1 (37)	1.69 (0.59)	0.68	3.02	1.27 (0.48)	0.62	3.32	0.95 (0.52)	0.53	2.21	1.54 (0.50)	0.34	2.76
2 (6)	1.46 (0.40)	1.06	1.97	1.06 (0.39)	0.62	1.66	0.86 (0.19)	0.60	1.14	1.30 (0.44)	0.75	2.00
3 (9)	1.71 (0.39)	1.28	2.15	1.32 (0.48)	0.75	1.96	1.15 (0.40)	0.75	1.81	1.70 (0.40)	1.38	2.42
4 (23)	2.21 (0.79)	1.28	5.28	2.04 (0.97)	1.06	5.00	1.40 (0.49)	0.64	2.44	2.11 (0.67)	1.48	4.50
Total (75)	1.83 (0.66)	0.68	5.28	1.49 (0.75)	0.62	5.00	1.10 (0.52)	0.53	2.44	1.71 (0.60)	0.34	4.50

Table 2. Canal wall thickness in the middle zone of the C-shaped canal

Type of C-shaped (N)	Distal			Mesial			Lingual			Buccal		
	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max
1 (37)	2.02 (0.44)	0.95	2.75	1.55 (0.40)	0.80	2.45	1.17 (0.57)	0.61	2.82	1.99 (0.40)	1.13	3.00
2 (6)	1.81 (0.26)	1.60	2.28	1.44 (0.40)	0.91	1.95	1.38 (0.49)	0.62	1.76	1.72 (0.47)	0.90	2.16
3 (9)	2.26 (0.48)	1.42	3.15	1.60 (0.98)	0.81	3.89	1.73 (0.26)	1.21	2.04	2.18 (0.30)	1.76	2.82
4 (23)	2.70 (0.77)	1.96	5.08	2.54 (0.82)	1.53	4.57	1.71 (0.52)	0.64	2.56	2.40 (0.75)	1.38	4.87
Total (75)	2.24 (0.64)	0.95	5.08	1.85 (0.78)	0.80	4.57	1.42 (0.57)	0.61	2.82	2.12 (0.56)	0.90	4.87

Table 3. Canal wall thickness in the coronal zone of the C-shaped canal

Type of C-shaped (N)	Distal			Mesial			Lingual			Buccal		
	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max	Mean (SD)	Min	Max
1 (37)	2.49 (0.41)	1.14	3.26	2.19 (0.43)	1.14	3.43	1.98 (0.43)	1.56	4.04	2.64 (0.39)	1.62	3.46
2 (6)	2.57 (0.44)	1.79	2.87	2.37 (0.38)	1.79	2.83	1.97 (0.25)	1.62	2.23	2.51 (0.34)	2.00	2.91
3 (9)	2.41 (0.85)	1.42	4.53	2.29 (0.78)	1.50	4.20	1.71 (0.55)	1.24	2.74	2.24 (0.52)	1.36	2.97
4 (23)	2.98 (0.69)	1.97	4.87	2.84 (0.56)	2.04	4.00	1.96 (0.41)	1.33	2.68	2.61 (0.69)	1.82	4.59
Total (75)	2.64 (0.61)	1.14	4.87	2.42 (0.59)	1.14	4.20	1.94 (0.43)	1.24	4.04	2.57 (0.52)	1.36	4.59

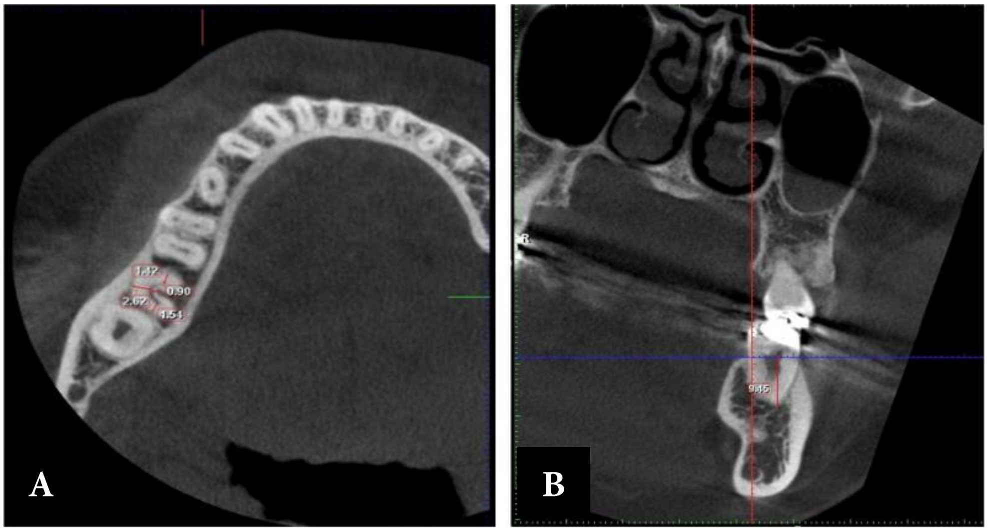

Figure 1. *A)* Axial view; determining the canal wall thickness; *B)* Sagittal view

Since most mandibular second molars were not upright and had lingual inclination, in the true axial view, the object indicator rod was positioned at the center of the tooth and the object cursor was positioned on the longitudinal axis of the tooth using the tool bar for changing the horizontal and vertical angles in order to achieve the highest resolution. When the longitudinal axis of the tooth was positioned parallel to the sagittal plane, tooth length was measured from the CEJ to the apex on a clear image of the tooth.

The axial sections of the teeth were evaluated from the pulp chamber floor to the apex. The number of axial sections depended on the tooth length. The sections were placed in a matrix of maximum 15 sections. The slice thickness was 0.2 mm with an interval of 1 mm between slices. The software obtained the first axial section from the apex and produced the next section 1 mm coronal to the previous slice. As the root canals were evaluated, the axial sections included the entire root length from the apex to the pulp chamber floor. The thickness of the buccal, lingual, mesial and distal walls around each canal was accurately measured on each section and by comparing the axial sections of each tooth, the canal path and changes in root length were assessed.

In each of the coronal, middle and apical regions, the thickness of canal walls from the internal to the external root surface was measured in the buccal, lingual, mesial and distal aspects in three axial sections to achieve comprehensive data and acquire a better perception of the C-shaped root canal wall thickness in these regions. In the coronal region, the first section was made at a 1-mm distance from the orifice and the next two sections were made 1 mm apical to the previous section. In the middle region of the root, the first section was made exactly in the middle of the root length. The second section was made 1 mm apical and the other one 1 mm coronal to the middle section. In the apical region, the first section was made at 1 mm from the apex and the other two sections were made 1 mm coronal to the previous section. The number of measurements was 36 for each tooth. In each of the coronal, middle and apical sections of the root, the mean of the three measurements on each wall was calculated. Twelve values were obtained for each tooth, indicating the mean thickness of buccal, lingual, mesial and distal walls in each of the coronal, middle and apical regions of each root.

Using axial sections, type of the C-shaped canal was revealed using Melton's classification [26] and changes in the path of root canal were assessed. C-shaped canal configuration was classified by Melton *et al.* [26] and further modified by Fan *et al.* [4, 27, 28]; Category I (C1)-continuous C-shaped root canal from the orifice to the apex of the root, Category II (C2)-one main root canal and a smaller one, Category III (C3)-two or three root canals, Category IV (C4)-an oval or a round canal and Category V (C5)-no canal lumen or there is one close to the apex.

In order to determine the thinnest root canal (Melton's types II and III C-shaped configurations) and compare the thickness of the same walls in the distal and mesial canals of the teeth with two or three canals (Melton's types II and III), the mean thickness of walls in distal canals was calculated and compared with the mean thickness of the same walls in the mesial canals (Figure 1).

Data were analyzed using the one-way ANOVA and post hoc Tukey's test in SPSS software (version 18, SPSS, Chicago, IL, USA).

Results

Thirty-six out of 75 CBCT scans belonged to males and the remaining 39 belonged to females. The prevalence of C-shaped root canals in the population was 13.6%.

Evaluation of axial sections revealed that Melton's type I was the most prevalent in the coronal and middle regions (49 and 45.3%, respectively). Types I and IV exhibited the highest prevalence in the apical region each with 40%.

Assessment of the axial CBCT sections of each tooth revealed that many of the canals in the middle or apical regions had variable configurations and number of canals compared to the coronal region. From 37 teeth that were Melton's type I in the coronal region, 3 teeth were Melton's type II in the middle region, 1 was type II in the apical region and 2 teeth were type III in the apical region. The root canal of one tooth was Melton's type III in the middle and apical region and one tooth was only Melton's type III in the apical region. The root canals of three teeth were Melton's type IV in the apical region.

The lingual wall in the coronal, middle and apical regions exhibited a significantly lower thickness than other walls ($P<0.05$). In addition, the lingual wall in the apical region was thinner than that in the coronal and middle regions. The mean thicknesses of this wall in the coronal, middle and apical regions were 1.94±0.43, 1.42±0.57 and 1.10±0.52 mm, respectively. Comparison of lingual wall thicknesses in the mesial and distal canals (which was the thinnest wall of these canals) revealed that the lingual wall, only in the middle region of the mesial canal, was significantly thinner than that in the distal canal ($P<0.05$) (Tables 1 to 3).

Discussion

In the current study, the most common configuration in the coronal region was Melton's type I, consistent with some previous studies [29, 30]. In the apical region, Melton's types I and IV were the most common configurations while type III was reported to be the most common type in another study [30]. This difference might be attributed to different study populations, differences between the resolution of the two CBCT units, printers and monitors. In another study, Melton's type II was the most common configuration in C-shaped root canals in mandibular second molars [14], which might be attributed to the selected population and the use of periapical radiography instead of CBCT which is more accurate [25, 31-33].

Several studies have evaluated mandibular second molars with C-shaped root canals using sectioning or Micro-CT of extracted teeth [4, 34], radiographic assessments [14], clinical observations [13] or CBCT [30]. Morphological assessments might be inaccurate in showing the anatomy of the root canal because the cross-sections are often damaged during sectioning. Also, these variations might have been caused by previous restorations [35]. One of the limitations of clinical observation is that only the pulp chamber floor is accessible for *in vivo* assessment of tooth morphology. Conventional radiography provides a 2D image of a 3D object and is less accurate than 3D CBCT technique. In addition, superimposition of images that occurs in conventional radiography does not occur in the CBCT technique. Micro-CT is a precise method with high resolution. However, this technique is time-consuming and can be implemented only in *in vitro* studies [34]. CBCT scanners provide high resolution and accuracy for assessment of root canal morphology. They can provide images with short exposure time. Furthermore, they are more affordable than CT and the equipment occupies smaller space compared to CT. Several studies have reported that CBCT is an accurate and reliable method for assessing the root canals and is superior to other methods [30, 36-42].

C-shaped canals do not follow a constant path from the orifice to the apex. The anatomy of the middle and apical portions of the root is not predictable based on the shape of the orifice [4, 13, 26, 38].

Non-surgical endodontic treatment of C-shaped canals has always been associated with the risk of strip perforation due to deep grooves and narrow isthmii [16]. In this study, the thinnest wall and its orientation was determined. The lingual wall was generally the thinnest in the coronal, middle and apical regions ($P<0.05$) and it became thinner from the coronal region toward the apical part of the root, consistent with the findings of another study [30]. Furthermore, in this study similar walls in the coronal, middle and apical regions of the distal and mesial canals were compared in order to determine the thinnest root canal wall in each part of the root with two or three canals (Melton's types II and III). None of the previous studies on mandibular second molars in Iranian population evaluated the thickness of the canal walls [5-7].

The CBCT scans have distortions which are more clear when the object is farther from the radiation plane. As this distortion occurred for all four root canal walls, the negative impact of this geometric error on determining the wall thickness was minimized. The number, shape and type of C-shaped root canals were well detectable in axial sections [43].

With all the benefits of CBCT, it cannot be commonly used for all cases because CBCT uses ionizing radiation and is not risk-free [44]. When more details are required for diagnosis, treatment planning, and epidemiological studies beyond that provided by conventional radiography, limited volume CBCT with low radiation dose and high resolution can be used for endodontic purposes.

Conclusion

It can be concluded that in Iranian population with C-shaped root canals in mandibular second molars, the lingual wall of the canal was the thinnest especially in the apical third. In teeth with separate root canals, the lingual wall in the middle region of the mesial canal was thinner than that in the distal canal. The use of CBCT can provide accurate 3D information about the root canal morphology and increases the success of surgical and non-surgical endodontic treatment.

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