Review Article

Prevalence of C-Shaped Root Canals in Iranian Population: A Systematic Review

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Abstract

Objective: Because of the great challenges in the diagnosis and treatment of "C" configuration and lack of any systematic information about its occurrence, the purpose of the present study is to determine the prevalence of C shaped root canals in Iranian population.

Methodology: An exhaustive search was undertaken to identify published and unpublished researches related to the C-shaped canals by using key words. The search of the MEDLINE database included all publications from 1966 to May 2012.Then selected articles were obtained and reviewed. Data evaluated and summarized in the data sheet included methodology, population, number of teeth per study (power), number of root canals, type of root canal configuration, and c-shaped canals.

Results: Six studies were included with total of 1062 teeth, all in mandibular second molars. The total incidence of C-shaped canals in Iranian population was obtained 6.96%.

Conclusions: The incidence of C-shaped canals in Iranian population is 6.96%, which seems much less than Asian populations but nearer to Middle East countries.

Key Words: C-shape; Root canal; Anatomy; Review, Systematic

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INTRODUCTION

The main goal of endodontic therapy is to prevent or heal apical periodontitis, this means cleaning, shaping, disinfection and three – dimensional obturation of the root canal system [1,2]. Many early and recent studies showed that a root with a single tapering canal is an exception rather than the rule [3,4].

The complexity of the root canal anatomy presents clinical challenges during the treat-

ment, so knowledge of pulpal anatomy and its variations are essential for long term success of endodontic treatments [3-6].

C-shaped canals are among these variations that were first described in 1979 by Cooke and Cox [7].

The name comes from the C-shaped cross sectional morphology of the root and root canal. in such cases, several discrete orifices are not seen; instead, the pulp chamber has a single ribbon-shaped orifice with 180 degree arc.

In mandibular molars the arc originates from the mesiolingual line angel, continues towards the buccal and terminates at the distal aspect of pulp chamber.

But its configuration may vary along the root depth so that the appearance of the orifices may not a good predictor of canal anatomy [8].

Melton et al. [9] first proposed the classification of C-shaped canals based on their cross-sectional shape.

Below the orifice level, the root structure can harbor a wide range of anatomic variations.

This can be classified into three basic groups:

The first, those with a continuous C shaped canal from orifice to apex ,second, semicolon shaped canals referred to those in which dentin separated one distinct canal from a buccal or lingual canal in the same section, and at last those with two or more distinct canals [7].

Table 1. The prevalence of C configuration in some populations (available studies)

Tooth type	Investigator	Method of study	Race	Sample size	Percentage%
Mandibular first premolar	Baisden et al. (1992)	Stereomicroscope and photography	Not stated	106	14
	Sikri and Sikri (1994)	Radiography	Not stated	112	10
	Lu et al. (2006)	Clearing tech	Chinese	82	18
	Zarrabi et al.(2003)	Stereomicroscope	Iranian	100	1
Mandibular second molar	Cooke and Cox (1979)	Clinically observation	American	Not stated	8
	Kuttler JC (1985)	Morphological studies	Japanese	Not stated	32
	Yang et al. (1988)	Clearing tech	Chinese	581	31.5
	Weine et al. (1988)	Clinical oriented invitro method	mixed	75	2.7
	Sutalo et al. (1998)	Injection of methylene blue	Not stated	112	12.5
	Weine (1998)	Combining the efforts of an endodontic study club	Mixed	811	7.6
	Haddad et al. (1999)	Scheduled endodontic treatment	Lebanese	94	19.1
	Gulabivala et al. (2001)	Clearing tech	Burmese	134	22.4
	Lambrianidis et al. (2001)	Periapical radiography	Greek	480	5
	Gulabivala et al. (2002)	Injection of Indian ink	Thai	60	10
	Al-Fouzan (2002)	Radiography	Saudi Arabian	151	10.6
	Seo and Park (2004)	Clinical observation	Korean	272	32.7
	Seo and Park (2004)	Teeth examined	Korean	96	31.3
	Cimilli et al. (2005)	Spiral CT	Turkish	491	8
	Jin et al. (2006)	Serial axial CT images	Korean	220	44.5
	Thomas et al. (2008)	Computed tomography	Hong Kong	207	30
	Present study (2012)	Systematic review	Iranian	1062	6.96
Third molar	Sidow et al. (2000)	Transparency	U.S	300	2.2
	Gulabivala et al. (2002)	Injection of Indian ink	Thai	173	11
Maxillary first molar	De Moor (2002)	Clinical observation	Not stated	2175	0.091
	Cleghorn et al. (2006)	Literature review	Mixed	2480	0.12
Maxillary second molar	Yang et al. (1988)	Clearing tech	Chinese	581	4.9

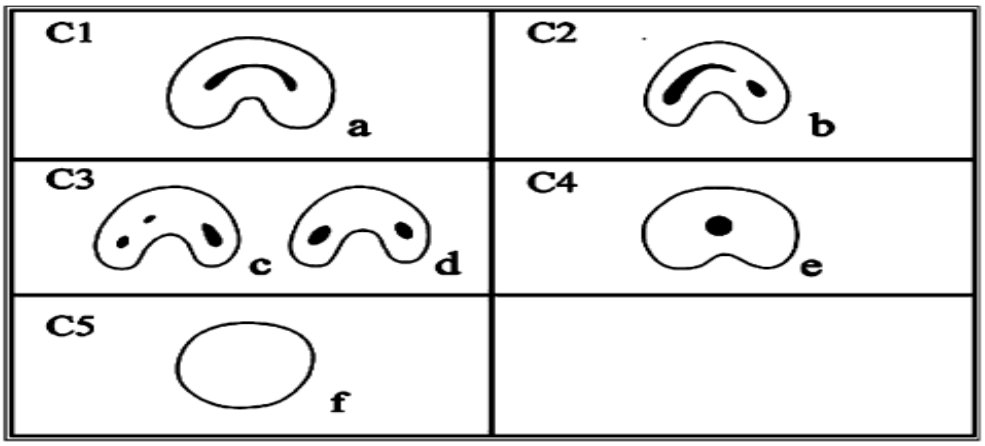

Fig 1. Classification of C-shaped canal configuration. (From Fan B, J Endod 2004; 30: 899-903)[9]

He modified Melton's method and offered a new classification as follows:

1. Category I (C1): The canal is in the form of an interrupted C. No separation or division is observed (Fig 1a).
2. Category II (C2): The root canal is in the form of a semicolon due to the discontinuation of the C outline (Fig 1b) but angle ά or β (Fig 2) have to be equal or greater than 60°.
3. Category III (C3): In this group 2 or 3 separate canals are present (Fig 1c and d) and both ά and β angles are smaller than 60° (Fig 3).
4. Category IV (C4): In this category just one round or oval- shaped canal is present in the C-shaped cross section (Fig 1e).
5. Category V (C5): No canal lumen is present (which is normally observed next to the tooth apex (Fig 1f).

As racial factors can influence the root canal anatomy, knowing the canal morphology of different racial groups is critical [10]. The frequency of C-shaped canals varies greatly among different ethnicities. Some text books of endodontics state that the C-shaped canal is not uncommon [11].

This is confirmed by basic studies in which frequency ranged from 2.7 to 8% [7,12].

Investigations conducted on Japanese [13] and Chinese [14, 15] showed a high incidence of C-shaped canals.

Therefore, it has been very well documented that the C-shaped root canal configuration has a greater prevalence among Asians compared to other ethnic populations. the 44.6% reported by Jin et al (Korean population)[17], 32.7% by Seo and Park (Korean population)[18], 31.5% by Yang et al (Hong Kong and Taiwan Chinese population)[19], 19.14% by Haddad et al (Lebanese population)[20],10.6% by Al- Fouzan (Saudi Arabian population)[21] and 8% by Cimilli et al (Turkish population)[22] in comparison with 7.6% frequency reported by Weine [23] and 5% by Lambrianidis et al (Greek population)[24] (Table 1).

The great differences evident among studies with regard to the prevalence of C- shaped canals of mandibular second molars in different populations may be attributed to racial difference and study method.

Because of the great challenges in the diagnosis and treatment of "C" configuration, the purpose of the present study is to determine the prevalence of C shaped root canals in Iranian population.

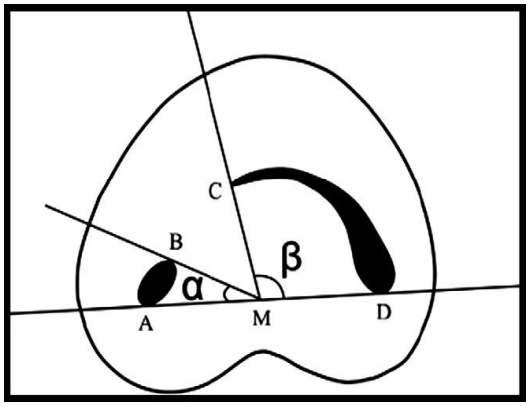

Fig 2. Measurement of angles for the C2 canal. Angle β is more than 60°. (*A* and *B*) Ends of one canal cross-section, (*C* and *D*) ends of the other canal cross-section; M, middle point of line AD;ά, angle between line AM and line BM; β, angle between line CM and line DM [8]

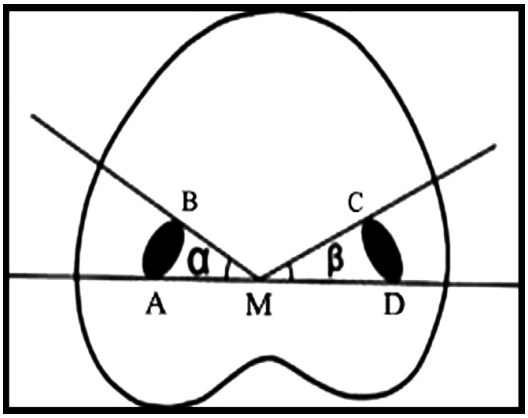

Fig3. Measurement of angles for the C3 canal. Both angle ά and angle β are less than 60°

MATERIALS AND METHODS

Literature Search and Data Extraction:

An exhaustive search was undertaken to identify published and unpublished literature related to the root anatomy, root canal morphology and prevalence of C-shaped canals in Iranian population. The MEDLINE database was searched via the PubMed search engine http://www.ncbi.nlm.nih.gov/pubmed. (last accessed on May 2012) by using the following search keywords: c-shaped canals, root anatomy, root canal morphology, mandibular first molars, maxillary molar, mandibular first premolars , maxillary lateral incisors , mandibular second molars.

The search included all years from 1966 to May 2012.

A similar search strategy was also applied by the Cochrane Database and manual searches, including journals and reference lists. No language restriction was applied to the search.51466 studies were found and subjected to the preliminary analysis. Titles and abstracts were evaluated to determine the relevance of each study to the anatomy of the teeth with c-shaped canals. Irrelevant studies were excluded from the list and 157 articles remained. Then the full texts of the selected articles were obtained and reviewed. Data extracted included methodology, population, type of canal configuration and prevalence of c-shaped canals.

One hundred and thirty one studies were excluded from the list and 26 remained in which the prevalence of this configuration was reported in different populations, one of them in an Iranian population [3].

Websites such as www.iranmedex.com, www.magiran.com and www.sid.ir were used to search all concerning studies published in Persian. From total of 23 researches found of this search, none of them had inclusion criteria. In order to get unpublished or published regional data concerning our study, a request was sent to all dental schools and dental research centers of the country. Eleven studies and thesis's which studied anatomy and morphology of extracted teeth were received. Among these studies addressing anatomy, those with C-shaped canals were selected, so 5 studies were excluded.

Inclusion and exclusion criteria:

Inclusion criteria

Among 51466 studies, in which anatomy and morphology of teeth and canals were evaluated, 157 studies about C- shaped canal were selected. In these studies anatomy and morphology of human extracted teeth were evaluated after access cavity preparation.

Reference lists of included studies were scanned to identify any potentially relevant articles.

Exclusion criteria

Studies which were only based on radiographic examination or any other methods except clinical examination after access cavity preparation or those with no mentioned ethnicity were excluded from our study.

RESULT

Included studies:

Seven studies were done upon C- shaped canals in Iranian population of which 6 met inclusion criteria with total of 1062 teeth (Table 2 and Fig 4). All of the included studies were in mandibular second molars and were performed with two study methods, clearing technique and direct observation after cavity or section preparation.

The study of Zarrabi et al.[25] on mandibular first premolar which showed the incidence of only 1% true C- shaped canal in samples, was excluded of this review because of lack of homogeneity with other studies.

Data summary of included studies:

In 2000, Abrahe et al [26] noted the prevalence of 5.8% in Ghazvin population. Injecting with Indian ink, all the 72 extracted mandibular second molars were demineralized and made clear with methyl salicylate, and the anatomy of their canals was studied.

It was found that 5.8% of the samples had C-shaped canals Ashraf et al [27] (2004) determined the frequency and anatomic form of the c-shaped canals in mandibular second molars in Tehran city.

The study performed on 123 extracted mandibular second molars. CEJ (Cementoenamel Junction), Mid Root and Apical cross sections were prepared by a diamond disc. Based upon the appearance of the roots and their cross sections the frequency and classification of the C-shaped canals were reported. On the basis of Haddad [20]_classification, 17 teeth (13.8%) have exhibited C-shaped canals that 3 were from category I (True C-shaped), 2 from category II and 12 were considered as category III.

Noormandi Poor et al [28] (2007), reported the prevalence of C-shaped mandibular second molars in Zahedan.

Table2. Studies included in this systematic review and their related prevalence of C- shaped canals in mandibular second molars

Tooth type	Investigator	Method of study	City of Iranian country	Sample size	Percentage%
Mandibular second molar	Abraheh A (2000)	Injection of Indian ink and stereomicroscope	Ghazvin	72	5.8
	Ashraf et al.(2004)	In vitro observation after access cavity preparation	Tehran	123	13.8
	Noormandi Poor et al. (2007)	Stereomicroscope	Zahedan	368	3
	Rahimi et al. (2008)	Injection of Indian ink	A North-Western Iranian population	139	7.9
	Hasheminia et al. (2009)	Injection of Indian ink	Isfahan & Shiraz	160	6.25
	Kuzekanani et al. (2011)	In vitro observation after access cavity preparation	Kerman	200	5
Mean of total				1062	6.96

Fig 4. Geographic distribution of the selected studies and their related prevalence of C- shaped canals in mandibular second molars

A total number of 368 mandibular second molars were collected. Performing the access cavities on the teeth, those with C-shaped orifices were isolated under direct dental unit light and 3x magnification.

The teeth were marked on three points: CEJ, midroot, and 2mm to apex and mounted in translucent acryl.

After taking the radiographic images from each tooth in facio-lingual and mesiodistal aspects, 0.2mm thickness cross sections were made by diamond disc. After that the sections were assessed under stereomicroscope by 40 magnifications.C shaped clinical canal forms and their radiographic views were classified according to Melton [9] and Fan [8] classifications, respectively. Out of total number, 312 teeth (84.8%) had two separate mesial and distal roots whereas 56 ones (15.2%) had fused roots, out of which 11 (3%) had C-shaped canals. The number and percent of teeth in each category and type was as following: 5(1.35%) , 4 (1.08%) and 2 (0.57%) for categories I,II and III, respectively.

Rahimi et al [3] (2008) determined the canal configuration and the prevalence of C-shaped canals in mandibular second molars in a North-Western Iranian population. After selecting a total of 139 extracted mandibular second molars, they were injected and made clear by using Indian ink and Nitric acid, respectively.They reported that 7.2% of the teeth had C-shaped canals and that configuration was seen mostly in single-rooted mandibular second molars.

Hasheminia et al [29] (2009) evaluated the canals form in mandibular first and second molars in Isfahan and Shiraz. By using clearing technique and dye penetration, it was found that among the 80 mandibular second molars, 6.25% had C-shaped canals.

Kuzekanani et al [30] (2011) determined the prevalence of C-shaped canals in mandibular second molars in Kerman population. Two hundred extracted mandibular second molars were collected. The teeth with C-shaped canals were isolated after access cavity preparation and inspecting the samples.

Then cross-sections were prepared at CEJ, mid –root and apical portion of the canals using a diamond disk. Of the total of the samples 10 teeth (5%) showed C-shaped canals.
From the result of this study, the total incidence of C-shaped canals in Iranian population was obtained 6.96%.

DISCUSSION

The variability of canal anatomy is a challenge in endodontic treatments, so preoperative knowledge of them is essential for success [1,2]. In C-shaped configuration, the root canals are connected through a thin web [3]. A comprehensive review of the literature on this anatomical variant is required for the correct diagnosis and treatment of this condition. There are different methods for studying the morphology of human permanent teeth. Some of the studies used extracted or endodontically treated teeth [10,31]. Radiography is the other method but the value of intra oral periapical radiographs for diagnosis C-shaped canals is debatable [32]. Cooke and Cox [7] reported that they were not very helpful; however Haddad [20] found common characteristics in almost all preoperative radiographs. Fan [8] determined radiographically that a tooth with a C-shaped canal always has a fused root with a longitudinal groove in the middle of the root. According to Lambrianidis [42], preoperative and working length periapical radiographs have low diagnostic value for detection of C-shaped configuration. However, identification of this configuration would be facilitated if preoperative, working length and postoperative radiographs are interpreted simultaneously.
Clearing and injection of dye is another method for studying the tooth morphology. The clearing technique is advantageous because it produces a 3D view of the canal system [18, 33] and instruments are not needed to enter the pulp system [10]. Therefore, this technique helps to conserve the essential form of the pulp system [34]. Due to the accuracy of the clearing technique, this method was used as a criterion for including studies in this systematic review. CT images are used as a new method for studying the morphology of the teeth. Jin [17] and Ruwan [35] used spiral computed tomography for studying the morphology of mandibular molars. Conventional radiographs give only a 2-dimentional view of the teeth, whereas CT images can show 3-dimentional images, and therefore much detail [36].
The occurrence of this variation is reported in mandibular first molars [37], maxillary molars [38, 39], mandibular first premolars [40], and even in maxillary lateral incisors [41], but it is most commonly found in mandibular second molars [37, 39, and 42].

Maxillary lateral incisors

Boveda [41] in 1999, reported a root canal treatment of an invaginated maxillary lateral incisor with 3 canals, 1 of which was a C-shaped one in an 11-years old girl.

Maxillary First Molar

C-shaped configuration was first described by Newton and McDonald [43] in maxillary molars in 1984.The odds of encountering a C-shaped canal in maxillary first molars was reported to be as low as 0.091% by De Moor et al, [44] in 2002.Also, Cleghorn et al, [45] in their review study stated that C-shaped root canal system was only detected in 0.12% of maxillary first molars.

Maxillary Second Molar

Yang [19] in 1988, by using a clearing technique, reported the prevalence of4.9% of C-shaped canals in the Chinese maxillary second molars which probably corresponded to both mesial and distal canals.

Maxillary and Mandibular Third Molars

Sidow [46] in his investigation in the year 2000 used the transparency method and reported that 2.2% of the third molar teeth in the U.S. population had C-shaped configuration.

On the other hand, Gulabivala [47] in 2002 found a surprisingly high prevalence of C-shaped roots (11%) in mandibular third molars of Thai population by injecting Indian ink.

Mandibular First Premolar

Baisden [48] in his study in 1992 detected C-shaped root canal systems in 14% of mandibular first premolars with the use of stereomicroscope and photography. By obtaining radiographs at two directions of buccolingual and mesiodistal and sectioning at three points, Sikri [49] in 1994 found a 10% incidence rate for C-shaped configuration in mandibular first premolars. An 18% incidence rate was announced by Lu et al, [40] in 2006 who used a clearing technique for screening of C-shaped root canal system in a Chinese population.

In an Iranian population, Zarrabi et al[25] (2003), using stereomicroscope for anatomic evaluation of the mandibular first premolars, found that only 1% of samples had true C-shaped canal.

Mandibular First Molar

Barnett [50] (1986) reported a case of a mandibular first molar with a normal mesiolingual orifice and a ~~.~~starts from mesiobuccal orifce and sweeps around the buccal wall to the distal canal orifice The groove extended down towards the apex and at the apical third was branched into two canals. Bolger and Schindler [37] in 1988 discussed a C-shaped groove detected in the mandibular first molar of a Caucasian male. The groove started from the distolingual orifice moving towards the distobuccal and across the buccal surface ending at mesiobuccal orifice. However, a separate mesiolingual orifice was evident. After tooth extraction, four separate apical foramina were observed.

Mandibular Second Molar

A high incidence of C-shaped roots and root canal systems (10-44.5%) in mandibular second molars has been reported in several studies conducted on Japanese [13], Chinese [19], Hong Kong Chinese [14], Lebanese [20], Korean [17, 18] and Thai [47] populations (Table 1) all revealing the higher prevalence of C-shaped configuration among Asians. At the same time, Weine et al [12], using a clinically oriented in vitro method, reported the incidence of 2.7%.

In 1990, by rendering the roots transparent and allowing the canal system to be observed by black ink infiltration, Manning [15] found that only 10% had true C-shapes.

By injecting contrast medium into the prepared teeth, Sutalo et al, [51] in 1998 found a 12.5% incidence rate for total and/or partial C-shaped root canal systems. Also, based on a report by Weine [23], a total of 7.6% of second molars that received root filling had C-shaped configuration.Haddad et al, [20] in 1999 employed two different detection systems and evaluated a total of 94 endodontically treated mandibular second molars radiographically and clinically during one year. He reported an incidence rate of 19.1% for C-shaped configuration among his Lebanese understudy population.

Gulabivala et al [33] (2001), using a canal staining and tooth clearing technique, reported the incidence of 22.4% in Burmese patients. A 22.4% incidence rate was announced by Gulabivala et al, [33] in 2001 who used a canal staining method along with tooth clearing in Burmese population. Also, Lambrianidis et al, [24] by evaluation and comparison of patients' periapical radiographs and their clinical diagnosis found that 5% of the endodontically treated teeth had C-shaped configuration.

In 2002, Gulabivala et al [47] and Al-Fouzan [21] noted the prevalence of 10% in Thai and 10.6% in the Saudi Arabian populations, respectively. By clinical examination of a Korean population, Seo and Park [18] in 2004 noticed that 32.7% of the mandibular second molars were C-shaped. However, this rate was found to be 31.3% by radiographic assessment of teeth (in-vitro). In recent studies, Cimilli et al [22] by using spiral computed tomography

imaging, Jin et al [17] by serial axial computed tomography images and Ruwan et al [35] by Spiral CT imaging, concluded that the prevalence of C-shaped canals in mandibular second molars were 8%, 44.5% and 30%, respectively. In 2010, Neelakantan et al.[52], evaluated Root and Canal Morphology of Mandibular Second Molars in an Indian Population by using a canal staining and tooth clearing technique and observed that 7.5% of mandibular second molars had C-shaped canals. In 2011, Zheng et al. [53], evaluated C-shaped root canal system in mandibular second molars in a Chinese population evaluated by cone-beam computed tomography and observed that 39% of mandibular second molars had C-shaped canals. Although this configuration was seen both in mandibular first premolar [25] and second molar of Iranian population (Table 2) but all the results which included in this review were in the latter. Among the studies that surveyed anatomy of mandibular second molars in Iranian population, 6 studies with total of 1062 teeth were included in this systematic review (Table 2 and Fig 1). Using the injection of Indian ink, Abrahe et al [26] (2000) noted the prevalence of 5.8% in Ghazvin population.
Ashraf [27] (2004) determined the frequency and anatomic form of the C-shaped canals in mandibular second molars in Tehran by in vitro observation after access cavity preparation. She noted the prevalence of 13.8%.
Noormandi Poor et al [28] (2007) used the stereomicroscope and reported the prevalence of 3% in Zahedan population. Rahimi et al [3] (2008) reported the prevalence of 7.2% for C-shaped canals in mandibular second molars in a North-Western Iranian population. It was also found that this configuration was seen mostly in single-rooted teeth.Evaluating the canals forms of mandibular second molars by injection of Indian ink, Hasheminia et al [29] (2009) stated that 6.25% of the samples had C-shaped canals. Kuzekanani et al [30] (2011) determined the prevalence of C-shaped canals in mandibular second molars in Kerman population. After access cavity preparation, 5% of the samples showed C-shaped canals. The difference between the results of these studies may be due to the study methods and also different ethnicity of people in all over the broad country. According the data of present study, the total incidence of C-shaped canals in Iranian population is 6.96%, which was less than the 44.6% reported by Jin (Korean population)[17], 31.5% by Yang (Hong Kong and Taiwan Chinese population)[19], 32.7% by Seo and Park (Korean population)[18], 19.14% by Haddad (Lebanese population)[20],10.6% by Al- Fouzan (Saudi Arabian population)[21], and 8% by Cimilli (Turkish population)[22]. On the other hand, this is higher than the 2.7% frequency reported by Weine [23] and 5% reported by Lambrianidis et al (Greek population)[24]. The great differences evident among studies with regard to the prevalence of C- shaped canals may be attributable to racial difference and study method.

CONCLUSION

Based upon the results of this systematic review, the incidence of C-shaped canals in Iranian population is 6.96%, which seems much less than Asian populations but nearer to Middle East countries.

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