C-shaped root canals of mandibular second molars in a Korean population: clinical observation and *in vitro* analysis

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Abstract

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Aim To investigate the incidence and morphology of C-shaped root canals of the mandibular second molar in a Korean population.

Methodology Through clinical observation, randomly selected 272 mandibular second molars of Korean patients were accessed and evaluated after taking radiographs for determination of working length. In an *in vitro* analysis, 96 extracted mandibular second molars of Korean patients were collected and embedded in resin using an Endodontic cube technique, and were sectioned at intervals of 1 mm. The specimens were then observed with a surgical microscope and were photographed. Canal configurations were assigned to one of three categories: Category I defined a C-shaped outline without any separation; Category II referred to those with canal configurations, where dentine separated one distinct canal from a buccal or lingual C-shaped canal; Category III had two or more discrete and separate canals.

Results In clinical observation, 89 of 272 teeth (32.7%) had C-shaped canals. Of the 96 teeth examined *in vitro*, 30 (31.3%) had C-shaped canals. Upon *in vitro* analysis, only 1 tooth at the subpulpal level and 10 teeth at the apical 1 mm level were categorized under Category III.

Conclusion There was high prevalence of C-shaped root canals in the mandibular second molars of Koreans. C-shaped canals having semicolon and continuous shapes at the canal orifice have a high possibility of being divided into two or three canals in the apical region.

Keywords: C-shaped canal, mandibular molar, morphology.

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Introduction

C-shaped canals may occur in mandibular first molars (Bolger & Schnidler 1988) and maxillary molars (Dankner *et al.* 1990), but are most commonly found in mandibular second molars. Cooke & Cox (1979) described three cases of C-shaped mandibular second molars.

Textbooks on Endodontics state that C-shaped canals in mandibular second molars are not uncommon (Walton & Torabinejad 1996). Weine *et al.* (1988) and Weine (1998) reported that out of 75 extracted mandibular second molars obtained in the Chicago area, USA, one tooth (1.3%) had a single canal, two teeth (2.7%) were C-shaped and 62 (7.6%) of 811 root-filled mandibular second molars were identified as C-shaped. Furthermore, investigations conducted on Japanese (Kotoku 1985) and Chinese populations (Walker 1988, Yang *et al.* 1988) showed a high incidence of C-shaped canals (31.5%). It has thus been established that this particular anatomy is more frequent in Asian ethnic groups (Manning 1990).

Mandibular second molars with a C-shaped canal system have many variations in canal configuration. Once these configurations are recognized, technique modifications of cleaning, shaping and filling the canal system are required. The purpose of this study is to investigate the incidence and characteristics of the C-shaped root

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canal anatomy of mandibular second molars in a Korean population.

Materials and methods

Clinical observation

Randomly selected mandibular second molars ($n = 272$) scheduled for root canal treatment were examined over a 1-year period in the Department of Endodontics, Samsung Medical Center, Seoul, Korea. Those having C-shaped canals were detected and counted using radiographic and clinical examination. Two preoperative radiographs were taken, one with a 90° angulation to the tooth in a buccolingual direction and the other at a mesial angle of approximately 20°, to allow better visualization of the buccolingual anatomy. The radiographs were examined on a viewer using a peripheral block and a ×6 aspheric magnifying lens. The number and position of root canals were noted. Two postoperative radiographs, using the same method as the preoperative radiographs, were taken to confirm canal configuration.

The clinical investigation was conducted by scrutinizing the pulp chamber and canal entrance following

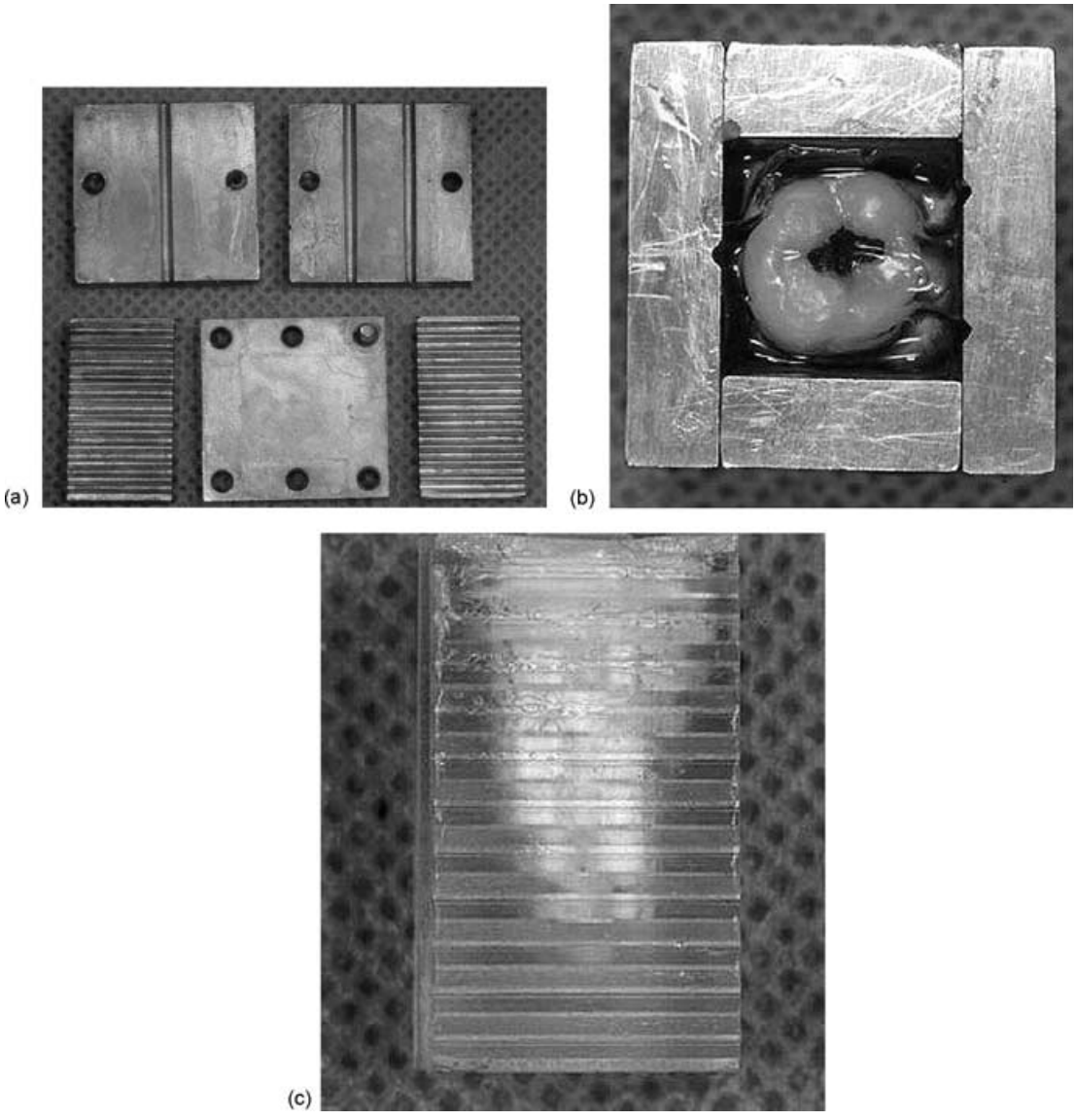

Figure 1 (a) Components of the endodontic cube; (b) upper view of resin-embedded specimen in the endodontic cube; and (c) lateral view of resin-embedded specimen having indentations for orientation of cutting are shown.

access. After probing the root canals with a size 10 or 15 K-file (Dentsply Maillefer, Ballaigues, Switzerland), radiographs were taken to confirm the canal morphology.

In vitro analysis

Ninety-six extracted mandibular second molar teeth from indigenous Korean patients were collected. After the access cavity was prepared, the teeth were placed in 2.5% sodium hypochlorite solution for 24 h to dissolve the organic tissue of the root surface and root canal system. They were then washed in running water for 2 h. The specimens were immersed in methylene blue dye for 10 s to distinguish the external outline of the embedded tooth within each section.

The Endodontic Cube consisted of five brass components with 10 hexed screws (Fig. 1a). The tooth was correctly oriented within the unset resin inside the Endodontic Cube and held in position with sticky wax on the occlusal surface (Fig. 1b). Acrylic resin (Orthojet, Lang Dental Mfg. Co., Wheeling, IL, USA) was flowed into the Endodontic Cube (Kuttler *et al.* 2001). The Endodontic Cube was then placed in a pressure container with water just below the top level of the cube. The acrylic resin was subjected to pressures of 20 psi for 15 min to minimize the setting expansion of the acrylic block.

Using the horizontal grooves on the opposing surfaces as a guide, the resin block was sectioned using an Isomet–Buehler Diamond disc of 0.3 mm thickness (Buehler Ltd, Evansonston, IL, USA) at intervals of 1 mm (Fig. 1c). The specimens were observed under good lighting with a surgical microscope and photographed with a digital camera (Coolpix 995, Nikon, Tokyo, Japan). The root canal system from the canal orifice to the apex was divided into five levels and was categorized at each level because the length of the root was not identical (Fig. 2).

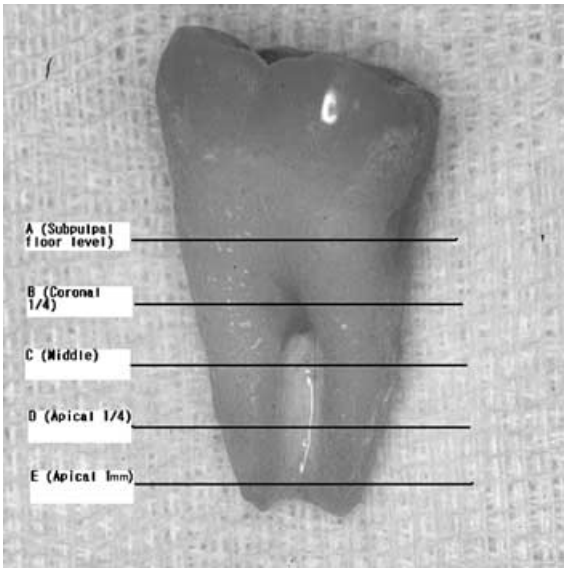

Figure 2 Five horizontal levels of the root.

Classification of root canal anatomy

The canal configuration of each tooth observed clinically and in the laboratory were assessed and classified as one of the following three categories (Melton *et al.* 1991):

- Category I (the continuous C-shaped canal) defines a C-shaped outline without any separation (Fig. 3a).
- Category II (the 'semicolon'-shaped canal) refers to those with canal configurations where dentine separates one distinct canal from a buccal or lingual C-shaped canal (Fig. 3b).
- Category III (separated canals) refers to those with two or more discrete and separate canals (Fig. 3c).

Results

Upon clinical observation of 272 second mandibular molars, 87 (32.7%) exhibited C-shaped canals: 15 were classified as Category I, 57 as Category II and 17 as Category III. In the laboratory study of 96 extracted second mandibular molars, 30 (31.3%) exhibited C-shaped canals (Table 1). They were classified as 12 Category I, 17 Category II and 1 Category III canals at subpulpal floor level (Table 2).

In the laboratory study, the incidence of Category II canal was highest in all levels and the incidence of Category III increased at the apical level (Table 3). Thus, 17 teeth (57%) were Category II from levels A (subpulpal floor) to C (middle of the root), but only 11 teeth (37%) were Category II at level E (1 mm from the apex), and only 1 tooth (3%) was recorded in Category III at the subpulpal level, whereas 10 teeth were recorded in Category III at level E (Fig. 4).

Ten out of 30 teeth had the same category from the subpulpal floor level to the apical 1 mm level; the other categories changed (Table 4). No constant change of category in the area between two adjacent levels could be observed (Table 4).

Discussion

The mandibular second molars were chosen based on their location and crown shape. To make sure that the

teeth were of a pure ethnic Korean population, they were collected only from indigenous Korean patients.

After access preparation, thorough inspection of pulpal floor was performed before radiographs were exposed with files set to the apex (Weine 1998).

Studies on mandibular second molars have demonstrated a high incidence of C-shaped roots and canals (10–31.5%) in Chinese, Lebanese (Gaby *et al.* 1999) and Thai (Gulabivala *et al.* 2002) populations. These studies indicate that C-shaped canals are more frequent in Asians, especially from the Far East. In this study of a Korean population, both clinical observation and laboratory analysis showed a high incidence of C-shaped canals – 32.7 and 31.3%, respectively – to confirm the results of previous studies.

C-shaped canals with a single canal seemed to be an exception rather than a rule (Yang *et al.* 1988). Yang *et al.* (1988) found it to be a less frequent configuration (7.4%). In this study, Category II was by far superior in number upon clinical observation (64.0%), which is in accordance with the results of Yang *et al.* (1988). It was also relatively more frequent in the subpulpal and middle level in the laboratory analysis. However, at the apical level, there was no significant difference between the incidences of the three categories. This means that C-shaped canals, which have semicolon and continuous

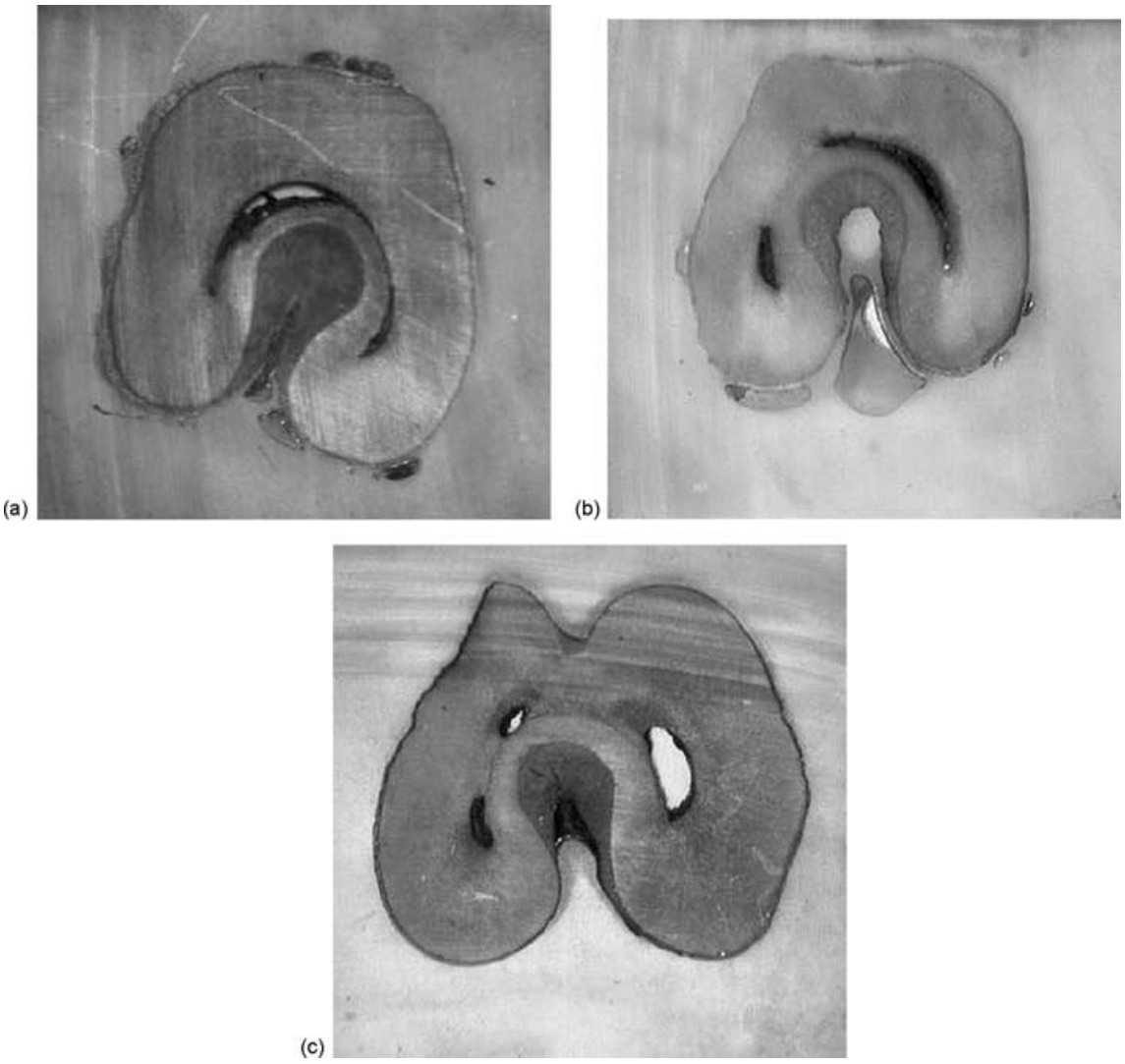

Figure 3 (a) Category I: C-shaped canal outline without any separation; (b) Category II: a canal configuration in which dentin separates one distinct canal from a buccal or lingual C-shaped canal in the same section; (c) Category III: shows two or more discrete and separate canals.

Table 1 The results of *in vitro* analysis of the 30 C-shaped second mandibular molars at five levels of the root

No.	Level				
	Subpulpal floor	Coronal 1/4	Middle	Apical 1/4	Apical 1 mm
1	Category I	Category I	Category II	Category III	Category III
2	Category I	Category II	Category II	Category I	Category I
3	Category I	Category I	Category II	Category II	Category II
4	Category I	Category II	Category I	Category II	Category III
5	Category II	Category II	Category II	Category III	Category II
6	Category II	Category II	Category II	Category II	Category II
7	Category I	Category I	Category III	Category III	Category III
8	Category II	Category II	Category I	Category I	Category I
9	Category II	Category I	Category II	Category II	Category III
10	Category II	Category III	Category III	Category III	Category III
11	Category II	Category II	Category II	Category III	Category III
12	Category I	Category I	Category I	Category I	Category III
13	Category I	Category II	Category II	Category II	Category I
14	Category III	Category III	Category II	Category II	Category II
15	Category I	Category I	Category I	Category I	Category I
16	Category II	Category I	Category I	Category II	Category II
17	Category I	Category I	Category I	Category I	Category I
18	Category I	Category I	Category III	Category II	Category III
19	Category II	Category II	Category II	Category II	Category II
20	Category II	Category II	Category II	Category II	Category II
21	Category I	Category I	Category I	Category I	Category I
22	Category II	Category II	Category II	Category II	Category II
23	Category II	Category II	Category III	Category III	Category III
24	Category II	Category II	Category II	Category II	Category II
25	Category I	Category I	Category I	Category I	Category I
26	Category II	Category II	Category II	Category III	Category II
27	Category II	Category II	Category II	Category II	Category I
28	Category II	Category II	Category II	Category II	Category I
29	Category II	Category II	Category II	Category II	Category I
30	Category II	Category III	Category III	Category III	Category III

shapes at the orifice level, have a high possibility of dividing into two or three canals in the apical region. This may be important in the root canal treatment of C-shaped mandibular second molars.

In the clinical observation, the incidence of Category I and II was 16.9 and 64.0%, respectively, whereas in the laboratory analysis, the incidence at the subpulpal floor level was 40 and 57%, respectively. Although there might be limitations in judging the exact morphology of the root canal system clinically, questions arise regarding the difference between the results of the two parts of the investigations. During clinical inspection of the pulpal floor of the access cavity, a narrow isthmus was found frequently. If a file could not be passed through this isthmus, the practitioner might consider the root canal as being separated. But in the laboratory analysis, these canals might merge just below the isthmus area. This might explain the differences in the results.

3-D reconstruction of two mandibular second molars showed that one was single-rooted with one C-shaped

Table 2 Incidence of C-shaped mandibular second molars

	Total teeth	Teeth with C-shaped canals (%)
Clinical observation	272	89 (32.7)
Category I	–	15 (16.9)
Category II	–	57 (64.0)
Category III	–	17 (19.1)
In vitro analysis (at subpulpal floor level)	96	30 (31.3)
Category I	–	12 (40)
Category II	–	17 (57)
Category III	–	1 (3)

Table 3 Incidence of categories by *in vitro* analysis at five levels of the root

Category	Level				
	Subpulpal floor	Coronal 1/4	Middle	Apical 1/4	Apical 1 mm
I	12	11	8	7	9
II	17	16	17	15	11
III	1	3	5	8	10

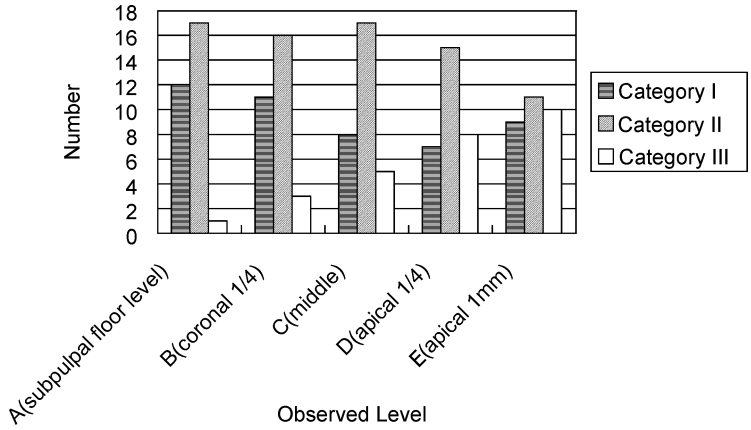

Figure 4 Incidence of categories of 30 C-shaped root canals at five levels.

Table 4 Number of C-shaped canals showing change of categories in the area between two adjacent levels of 30 C-shaped canals (*in vitro* analysis)

	Number of C-shaped canals
Unchanged case (from A to E levels)	10
Changed case	20
A∼B level	7
B∼C level	9
C∼D level	8
D∼E level	9

root canal with two foramina, and the other was double-rooted with two root canals, one C-shaped and the other thin, having a common foramen (Lyroudia *et al.* 1997).

Clinically, it is possible to overlook the fact that the canal may be connected in the coronal portion, yet separated in the apical region. When the canal orifice looks continuously connected at the subpulpal level, a separate root canal exiting at the apical level should be suspected, investigated and confirmed.

Melton *et al.* (1991) reported that C-shaped canals could change configuration at different levels. This laboratory study showed that 20 teeth (66.7%) had more than two categories in the five levels, but no consistent change of category in the area between two adjacent levels could be observed.

References

Bolger WL, Schnidler WG (1988) A mandibular first molar with a C-shaped root configuration. *Journal of Endodontics* **14**, 515–9.

Cooke HG, Cox FL (1979) C-shaped canal configurations in mandibular molars. *Journal of the American Dental Association* **99**, 836–9.

Dankner E, Friedman S, Stabholz A (1990) Bilateral C-shaped configuration in maxillary first molars. *Journal of Endodontics* **16**, 601–3.

Gaby YH, Walid BN, Hani FO (1999) Diagnosis, classification, and frequency of C-shaped canals in mandibular second molars in the Lebanese population. *Journal of Endodontics* **25**, 268–71.

Gulabivala K, Opasanon A, Ng YL, Alavia A (2002) Root and canal morphology of Thai mandibular molars. *International Endodontic Journal* **35**, 56–62.

Kotoku K (1985) Morphological studies on the roots of the Japanese madibular second molars. *Shikwa Gakuho* **85**, 43–64.

Kuttler S, Garala M, Perez R, Dorn SO (2001) The Endodontic Cube: a system designed for evaluation of root canal anatomy and canal preparation. *Journal of Endodontics* **27**, 533–6.

Lyroudia K, Samakovitis G, Pitas I, Lambrianidis T, Molyvdas I, Mikrogeorgis G (1997) 3D reconstruction of two C-shaped mandibular molars. *Journal of Endodontics* **23**, 101–4.

Manning SA (1990) Root canal anatomy of mandibular second molars. Part 2. C-shaped canals. *International Endodontic Journal* **23**, 40–5.

Melton DC, Krell KV, Fuller MW (1991) Anatomical and histological features of C-shaped canals in mandibular second molars. *Journal of Endodontics* **17**, 384–8.

Walker RT (1988) Root form and canal anatomy of mandibular second molars in southern Chinese population. *Journal of Endodontics* **14**, 325–9.

Walton R, Torabinejad M (1996) *Principles and Practice of Endodontics*, 2nd edn. Philadelphia, USA: W. B. Saunders Co., pp. 177–8.

Weine FS (1998) The C-shaped mandibular second molar: incidence and other considerations. *Journal of Endodontics* **24**, 372–5.

Weine FS, Pasiewics RA, Rice RT (1988) Canal configuration of the mandibular second molar using a clinically oriented *in vitro* method. *Journal of Endodontics* **14**, 207–13.

Yang ZP, Yang SF, Lin YL (1988) C-shaped root canals in mandibular second molars in Chinese population. *Endodontics and Dental Traumatology* **4**, 160–3.