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## Investigation of the root canal configuration of mandibular first molars in a Taiwan Chinese population

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#### Abstract

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**Aim** To investigate the root form and canal morphology of mandibular first molar teeth in a Taiwan Chinese population.

**Methodology** A total of 183 mandibular first molars were collected and examined visually through a dissecting microscope after rendering the teeth transparent. The number of roots, number of canals and canal configuration were recorded. The root canal morphology was categorized and compared according to Vertucci (1984).

**Results** Overall 46% of the mandibular first molars had four canals and 20% had extra-distal roots (distolingual root). In addition, 97% of the specimens

had two mesial canals and 46% had two distal canals. In total, 68% of teeth with two mesial canals had two separated apical foramina, and 33% of teeth with two distal canals had two apical foramina. The most common canal configurations (Vertucci, 1984) of mesial roots were type 4 (46%) and type 2 (23%). Type 1 was encountered in 54% of the distal roots.

**Conclusions** The frequency of the extra-distal root on the mandibular first molar was 20%, and the incidence of three canals (Vertucci's type 8 classification) with separate apical foramina at the apex of the mesial root was 6%. The three-rooted variation of the mandibular first molar appears to be a genetic characteristic of an Asiatic racial background.

**Keywords:** configuration, extra-distal roots, mandibular first molar, root canal, Taiwan Chinese population.

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#### Introduction

Successful root canal treatment depends on thorough mechanical and chemical cleaning, shaping and complete filling of the root canal system. Post-treatment disease occurs in many cases because the operator has failed to recognize the presence of an additional root canal. It is, therefore, of utmost importance that the dentist has a thorough knowledge of root canal morphology of the tooth being treated. The mandibular first molar is a frequently treated tooth and has a wide variety of root canal configurations (Skidmore & Bjorndal 1971). Many investigations have revealed the incidence of four canals in different populations ranging from 4% to 57% (Hess 1925, Tratman 1938, Green 1955, Skidmore & Bjorndal 1971, Vertucci 1984). In addition, the frequency of three-rooted mandibular first molars of Mongolian origin was

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reported to range from 2% in Saudi Arabia (Younes et al. 1990) to 23% (Tratman 1938, Laband 1941, Pedersen 1949, Curzon & Curzon 1971, De Souza-Freitas et al. 1971, Somogyi-Csizmazia & Simons 1971, Turner 1971, Curzon 1974, Hochstetter 1975, Jones 1980, Reichart & Metah 1981, Walker & Quackenbush 1985. Walker 1988. Ferraz & Pecora 1992. Yew & Chan 1993, Al-Nazhan 1999, Gulabivala et al. 2001, 2002); figures that are at variance with races, such as Caucasian, African, Eurasian and Indian (Taylor 1899, Drennan 1929, Shaw 1931, Tratman 1938, De Souza-Freitas et al. 1971, Skidmore & Bjorndal 1971, Turner 1971, Curzon 1973, Steelman 1986, Ferraz & Pecora 1992, Sperber & Moreau 1998, Sert et al. 2004). This high prevalence of three-rooted mandibular molar appears to be genetically determined (Tratman 1938, De Souza-Freitas et al. 1971, Turner 1971, Curzon 1974). As there is a divergence of opinion about the root and the canal morphology of the mandibular first molar, it was decided to conduct a detailed investigation of this tooth in a Taiwan Chinese population. The purpose of this study was to prepare a detailed investigation and to categorize the root and root canal anatomy in a sample of mandibular first molars of Taiwan Chinese origin using a clearing technique.

#### **Materials and methods**

A total of 183 mandibular first molars were extracted and collected from the Department of Oral and Maxillofacial Surgery of the Veterans General Hospital in Taiwan. No specimens had seen root filled and no severe crown destruction had occurred. Immediately after extraction, the teeth were fixed in 10% formalin solution. The residual soft tissues, bone fragments and calculus were cleansed and removed by currettes and ultrasonic scalers. Each specimen was first examined visually and categorized by the number of roots.

An access cavity through the occlusal surface of the teeth was prepared with a No. 6 diamond round bur. All orifices in the floor of the pulp chamber were detected carefully along the anatomic lines with a DG-16 endodontic explorer (Hu-Friedy, Chicago, IL, USA). The specimens were then placed in 5.25% sodium hypochlorite solution for 48 h in order to dissolve organic debris and pulp remnants.

A standardized technique utilizing transparent specimens was employed (Robertson *et al.* 1980). The specimens were first decalcified at room temperature in 5.0% nitric acid that was changed daily for 3 days, and then rinsed in running tap water for 4 h. On completion of the decalcification process, haematoxylin dye was injected into the pulp cavity through a 27-gauge needle until the dye material leaked out of the apical foramina. The specimens were dehydrated in successive solutions of ethyl alcohol, starting with an 80% solution overnight, followed by a 90% solution for 1 h, and then rinsed with 100% ethyl alcohol solution twice for 1 h each time. Finally, the specimens were placed in methyl salicylate solution for approximately 2 h to induce transparency. The cleared teeth were stored in methyl salicylate solution for dissecting microscope examination at  $100 \times$  magnification.

#### Results

These results of this study are summarized in Tables 1, 2 and 3. Canal configurations of the specimens were

 Table 1
 Number of roots and canals in mandibular first molars

	Number of roots				Number of canals per tooth			
	One	Two	Three	Four	One	Two	Three	Four
Number of tooth	6	141	36	0	0	6	93	84
Percentage (%)	3	77	20	0	0	3	51	46

Total specimens 183.

**Table 2** Number of root canals, apical foramina and region of canal bifurcation in mandibular first molars

	Mesial roo	t	Distal root		
183 Teeth	One canal	Two canal	One canal	Two canal	
Foramina					
One apex	6 (3%)	52 (28%)	99 (54%)	24 (13%)	
Two apex		125 (68%)		60 (33%)	
Bifurcation					
Middle third	10%		25%		
Apical third	65%		65%		
Apical foramen	25%		10%		

**Table 3** Canal configuration and the type of root canal in mandibular first molars

183 teeth	Canal configuration (type)								
	I	П	III	IV	V	VI	VII	VIII	
Mesial root	6	54	5	101	3	3	1	10	
Percentage (%)	3	30	2	55	2	2	1	5	
Distal root	99	23	12	46	3	0	0	0	
Percentage (%)	54	12	7	25	2	0	0	0	

Classifications were based upon the reports of Vertucci (1984).



**Figure 1** Canal configuration of the specimens were classified according to the scheme devised by Vertucci (1984).

recorded and classified into eight different types according to the scheme devised by Vertucci (1984) (Fig. 1).

Of the 183 examined teeth, 141 had two roots (77%) and 36 (20%) had a distolingual root. Four canals in the mandibular first molar occurred in 84 cases (46%; Table 1). The mesial root had two canals in 177 teeth (97%) and only one canal in 6 (3%). Those distal were two canals in 84 teeth (46%) and one canal in 99 (54%; Table 2). In addition, 71% of the teeth with a two-canal mesial root had two separate apical foramina, and 61% of teeth with two distal canals had two apical foramina. Bifurcation canals in the mesial root revealed that 10% joined in the middle third, 65% merged in the apical third and the other 25% came together at the apical foramina. In the distal root, 25% merged in the middle third, 65% in the apical third and 10% joined in the apical foramina (Table 2). Moreover, type 4 canal configuration (55%) was the most common type in the mesial roots of the first mandibular molar and type 1 (54%) in distal roots. Three canals at the apex (apical foramina) were found in 6% and located only in the mesial root of the mandibular first molar (Table 3).

#### Discussion

Skidmore & Bjorndal (1971) first drew attention to the prevalence of four canals in the mandibular first molar in more than a quarter (29%) of teeth examined. The

<b>Table 4</b> Number of root canals in the mandibular first molar from previous st
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		Mesial root (%)			Distal root (%)			
Study	Year	1	2	3	1	2	Four canals (%)	
Skidmore & Bjorndal	1971	7	93	0	71	28.9	28.9/45	
Pineda & Kuttler	1972	13	87	0	73	27	27.0/300	
Vertucci & Williams	1974	12	87	1	70	30	30.0/100	
Walker	1988	3	96	1	55	45	45.0/100	
Yew & Chan	1992	6	94	0	69	31.5	31.5/832	
Al-Nazhan	1999	0	100	0	42	57.7	57.7/251	
Gulabivala <i>et al.</i>	2001	60	78	1	111	28	28.0/118	
Wasti <i>et al.</i>	2001	0	97	3	50	47	47.0/30	
Sert et al.	2004	102	95	3	174	26	26.0/200	

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finding was substantiated by Pineda & Kuttler (1972) and Vertucci & Williams (1974) (Table 4). The variation in four canals mandibular first molar was reported to be from 28.9% to 57.7% (Somogyi-Csizmazia & Simons 1971, Turner 1971, Jones 1980, Reichart & Metah 1981, Walker 1988, Yew & Chan 1993, Al-Nazhan 1999, Wasti *et al.* 2001). In the present investigation, the occurrence of four canals in the mandibular first molar in Taiwan Chinese population was higher and approached almost one-half (46%) of the teeth. These results are similar to those of Walker (1988) and Wasti *et al.* (2001), who reported 45% and 47% of teeth had four canals (Table 4). Some studies have shown that bifurcation of the distal root influenced the prevalence of separate canals and/or apical foramina. An investigation of a Saudi Arabian population (Al-Nazhan 1999) reported a higher occurrence of four canals in 57.7% when only 5.97% of two distal canals had two separate apical foramen (Table 4).

 Table 5
 Previous study of the prevalence of three-rooted mandibular first molar

Study	Year	Populations	Three roots teeth/total teeth no	Percentage of total (%)	Study method
Taylor	1899	United Kingdom	4/119	3.4	Visual
Bolk	1915	Netherlands	18/1713	1.0	Radiography
Campbell	1925	Australian Aborigine	0/176	0.0	Uncertain
Hjelman	1928	Finland	-	0.9	Uncertain
Fabian	1928	Germany	-	1.6	Uncertain
Shaw	1931	African Bantu	0/68	0.0	Uncertain
Tratman	1938	Singapore Chinese	95/1615	5.8	Radiography
		Malaysian	41/475	8.6	
		Japanese	12/110	10.9	
		Indians	1/453	0.2	
		Eurasians	11/262	4.2	
Laband	1941	Malaysian Borneo	11/134	8.2	Visual
Pedersen	1949	Greenland Eskimo	8/64	12.5	Visual
Somogyi-Csizmazia & Simons	1971	Canadian Indians	39/250	16.0	Visual
De Souza-Freitas <i>et al.</i>	1971	Japanese	83/233	17.8	Radiography
		European	27/422	3.2	
Skidmore & Bjorndal	1971	Caucasian	1/45	2.2	Visual
Turner	1971	Aleut Eskimo	84/263	32.0	Radiography
		American Indians	116/1983	5.8	
Curzon & Curzon	1971	Keewatin Eskimo	28/98	27.0	Visual
Curzon	1973	United kingdom	13/377	3.4	Visual
Curzon	1974	Baffin Eskimo	15/69	21.7	Visual
Vertucci & William	1974	America	0/100	0.0	Visual
Hochstetter	1975	Guam	52/400	13.0	Radiography
Jones	1980	Chinese	7/52	13.4	Visual
		Malaysian	25/149	16.0	
Reichart & Metah	1981	Thai	70/364	19.2	Visual
Walker & Quackenbush	1985	Hong Kong Chinese	31/213	14.6	Radiography
Steelman	1986	Hispanic	5/156	3.2	Uncertain
Walker	1988	Southern Chinese	15/100	15.0	Visual
Loh	1990	Singapore Chinese	24/304	7.9	Uncertain
Younes <i>et al.</i>	1990	Saudi	17/581	2.92	Uncertain
		Egyptian	6/739	0.01	
Ferraz & Pecora	1992	Japanese	12/105	15.0	Radiography
		Caucasian	3/106	4.2	
		Negroid	5/117	2.8	
Yew & Chan	1992	Taiwan Chinese	179/832	21.5	Radiography
Sperber & Moreau	1998	Senegalese	15/480	3.0	Radiography
Al-Nazhan	1999	Saudi Arabian	15/251	5.97	Radiography
Wasti <i>et al.</i>	2000	South Asian Pakistanis	0/30	0.0	Visual
Gulabivala <i>et al.</i>	2001	Burmese	14/139	10.0	Visual
Gulabivala <i>et al.</i>	2002	Thai	15/118	13.0	Visual
Sert et al.	2004	Turkish	0/200	0.0	Visual
Chen <i>et al.</i>	2009	Taiwan Chinese	36/183	19.5	Visual

Previous studies on the frequency of three-rooted mandibular first molars in various races have been performed (Table 5). The occurrence of three-rooted lower first molar in Caucasians varied from 1% to 4% (Taylor 1899, Bolk 1915, De Souza-Freitas et al. 1971, Skidmore & Bjorndal 1971, Curzon 1973, Steelman 1986, Ferraz & Pecora 1992, Sert et al. 2004). In African populations, a maximum of 3% was found (Drennan 1929, Shaw 1931, Sperber & Moreau 1998). In Eurasian and Indian populations, the frequency was less than 5% (Tratman 1938). The majority of studies have been conducted on races of Asian origin where the frequency has ranged from 6% to 40% (Tratman 1938, Laband 1941, Pedersen 1949, Curzon & Curzon 1971, De Souza-Freitas et al. 1971, Somogyi-Csizmazia & Simons 1971, Turner 1971, Curzon 1974, Hochstetter 1975, Jones 1980, Reichart & Metah 1981, Walker & Ouackenbush 1985, Walker 1988, Ferraz & Pecora 1992, Yew & Chan 1993, Al-Nazhan 1999, Gulabivala et al. 2001, 2002). Those reports showed that canal morphology of the mandibular first molar in Chinese populations has a greater tendency towards four canals with a separated extra-distal root and apical foramina. In those races, the three-rooted variation occurs in such a high percentage of individuals that it can be mentioned as a special characteristic of their dentition. It is generally believed that the accessory root of the mandibular first molar is always situated distolingually and has a curve at the apex. Owing to the high percentage of two distal canals, classical triangular access preparation during root canal treatment should be extended towards the distolingual direction in a rectangular form to improve canal identification. Meanwhile, the anomally must be recognized and considered in endodontics as well as exodontics during tooth management.

According to Grossman (1970), the two-canal configuration of both the mesial and distal roots in the mandibular first molar can be divided throughout their length, forming two separate apical foramina, which might unite and terminate in a common apical foramen, or communicate with each other partially or completely by means of transverse anastomosis. Vertucci (1984) reported the occasion of two canals of the mesial or distal canal in the mandibular first molar merging into one, which joined at 10% of the middle third of the root, 60% merged in the apical third and 30% came together at the apical foramen. Their investigation was similar to the canal forms that were found in this study (Table 2). Vertucci (1984) also reported the prevalence of type 4 canals in the mesial root of mandibular molars to be 51% and type 2 in 28%. Type 1 canal forms were seen in 70% of the distal roots. Sert *et al.* (2004) encountered type 1 root canal configurations in 54% of distal roots, type 2 in 44% and type 4 in 43% of mesial roots. In this present study, most mesial roots of the mandibular first molars had two canals (77%), and three canals were found in 20%. A wide variation of canal configurations was also demonstrated. The most common were type 4 (55%) and type 2 (23%) in mesial roots. Therefore, the results of the present investigation are in agreement with those of Vertucci (1984) and Sert *et al.* (2004).

#### Conclusions

(1) The occurrence of four canals in the mandibular first molar was 46%, and 97% of the mesial root had two canals. (2) In roots with two canals, 68% of the mesial canal and 33% of the distal canal remained separate throughout their length. (3) The incidence of three canals (type 8 canal configuration) at the mesial root was found to be present in 6% of cases. (4) The frequency of the extra-distal root in the present study and the differences compared with those studies listed in Table 5 indicate that three-rooted variation of the mandibular first molar may be genetically characteristic to an Asiatic racial background. Morphological knowledge of pulp cavity is essential before a dentist can approach any endodontic procedure. Understanding of the variations of root morphology and careful evaluation using angled radiographs before treatment is strongly recommended in order to treat root canal successfully.

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