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Analysis of the gutta-percha filled area in C-shaped mandibular molars obturated with a modified MicroSeal technique

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Abstract

Ordinola-Zapata R, Bramante CM, de Moraes IG, Bernardineli N, Garcia RB, Gutmann JL. Analysis of the gutta-percha filled area in C-shaped mandibular molars obturated with a modified MicroSeal technique. *International Endodontic Journal*, **42**, 186–197, 2009.

Aim To analyse the gutta-percha filled area of C-shaped molar teeth root filled with the modified MicroSeal technique with reference to the radiographic features and the C-shaped canal configuration.

Methodology Twenty-three mandibular second molar teeth with C-shaped roots were classified according to their radiographic features as: type I – merging, type II – symmetrical and type III – asymmetrical. The canals were root filled using a modified technique of the MicroSeal system. Horizontal sections at intervals of 600 μm were made 1 mm from the apex to the subpulpal floor level. The percentage of gutta-percha area from the apical, middle and coronal levels of the radiographic types was analysed using the Kruskal–Wallis test. Complementary analysis of the C-shaped canal configurations (C1, C2 and C3) determined from cross-sections from the apical third was performed in a similar way.

Results No significant differences were found between the radiographic types in terms of the percentage of gutta-percha area at any level ($P > 0.05$): apical third, type I: 77.04%, II: 70.48% and III: 77.13%, middle third, type I: 95.72%, II: 93.17%, III: 91.13% and coronal level, type I: 98.30%, II: 98.25%, III: 97.14%. Overall, the percentage of the filling material was lower in the apical third ($P < 0.05$). No significant differences were found between the C-shaped canal configurations apically; C1: 72.64%, C2: 79.62%, C3: 73.51% ($P > 0.05$).

Conclusions The percentage of area filled with gutta-percha was similar in the three radiographic types and canal configuration categories of C-shaped molars. These results show the difficulty of achieving predictable filling of the root canal system when this anatomical variation exists. In general, the apical third was less completely filled.

Keywords: configuration category, C-shaped canal system, gutta-percha filled area, radiographic type, root canal obturation.

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Introduction

The C-shaped canal is an anatomical variation that was first reported by Cooke & Cox (1979) and mostly seen in mandibular second molars (Manning 1990). Many reports describe this variation amongst different populations with it prevalence reported to be between 2.7% and 31.5% (Yang *et al.* 1988, Weine

1998, Haddad *et al.* 1999, Gulabivala *et al.* 2001, 2002). These studies indicate that the occurrence of C-shaped canals is more frequent in Asian populations than in other races.

The C-shaped canal configuration has special features, such as: fused root with a longitudinal groove in the middle of the root, on its lingual or buccal aspect, a pulp chamber floor usually deeply positioned with an uncommon anatomical appearance (Min *et al.* 2006), and the main anatomic feature of the C-shaped canals in mandibular molars is the presence of one or more isthmuses connecting individual mesial and distal canals (Melton *et al.* 1991).

The complexity of C-shaped canals requires appropriate cleaning and shaping procedure as well as a modified filling technique. There are few reports in the literature concerning the evaluation of cleaning, shaping and filling of C-shaped mandibular molars. The filling of C-shaped canals with the current technique is based upon clinical reports (Ricucci *et al.* 1996, Walid 2000, Lynn 2006).

The quality of root fillings is generally evaluated by two-dimensional radiographs (Hörsted-Bindslev *et al.* 2007), leakage models (De-Deus *et al.* 2008), and by a cross-sectional method (Eguchi *et al.* 1985, Cathro & Love 2003), which enables the distribution of the root filling materials, such as gutta-percha and sealer, inside the canal to be determined. According to recent investigations, the ideal outcome in canal filling is a high volume of the core material, usually gutta-percha, and a minimal volume of sealer (De-Deus *et al.* 2007, Gulsahi *et al.* 2007).

The MicroSeal system is a thermomechanical filling technique that uses a laterally compacted master gutta-percha cone and placement of α gutta-percha to backfill the canal. Some modifications of this technique were suggested by Maggiore (2004) with the use of accessory gutta-percha points and the use of vertical compaction with a plugger to increase the adaptation of the gutta-percha to the root canal. These suggestions could be useful for the filling of C-shaped canals.

The aim of this study was to analyse the gutta-percha filled area of C-shaped mandibular molars filled with the modified MicroSeal thermomechanical gutta-percha technique in relation to various radiographic features and the C-shaped canal configuration.

Materials and methods

Collection of teeth

Twenty-three extracted mandibular second molars with C-shaped roots were obtained from the Endodontic Department, Dental School of Bauru, University of São Paulo, Brazil. The selected C-shaped roots were fused with a longitudinal groove on the lingual or buccal surfaces. The teeth were stored in saline at 4 °C until use. The patients gender and age were unknown. After preparation of standard access cavities, the canal orifices were identified. Only those mandibular molars with complete or incomplete C-shaped canal orifices were used, type I, II or III as classified by Min *et al.* (2006). Then each tooth was positioned with the buccal surface parallel to a dental radiographic film, Kodak InSight (Eastman Kodak Company, Rochester, NY, USA). The radiograph was exposed in an orthoradial projection using a dental X-ray machine (Gnatus XR6010, Ribeirão Preto, SP, Brazil). All radiographs were examined on a light-box with a magnifying glass by four endodontic postgraduate students according to a set of written criteria including photographs of representative cleared teeth from a pilot study for a better identification of the anatomy. The teeth were classified according to their radiographic appearance into the following categories according to Fan *et al.* (2004b), Gao *et al.* (2006) and Fan *et al.* (2007):

Type I (merging type)

For type I, canal images merged into 1 major canal before exiting from the apical foramen. A faint radiolucent region in the coronal and/or middle portion of the canal system may be apparent (See Fig. 1a).

Type II (symmetrical type)

For type II, there were separate mesial and distal canals. The mesial and distal canals appeared to be symmetrical in size and continued separately to the apex. The mesial and distal borders of each canal were clear over their length (see Fig. 1b).

Type III (asymmetrical type)

For type III, there were separate mesial and distal canals. The mesial and distal canals appeared to be asymmetrical in size and continued separately to the apex. The distal border of distal canal and both borders of the mesial canal were clear, but the mesial border of the distal canal was indistinct, making it seem wider than the mesial canal (See Fig. 1c). Any controversy in

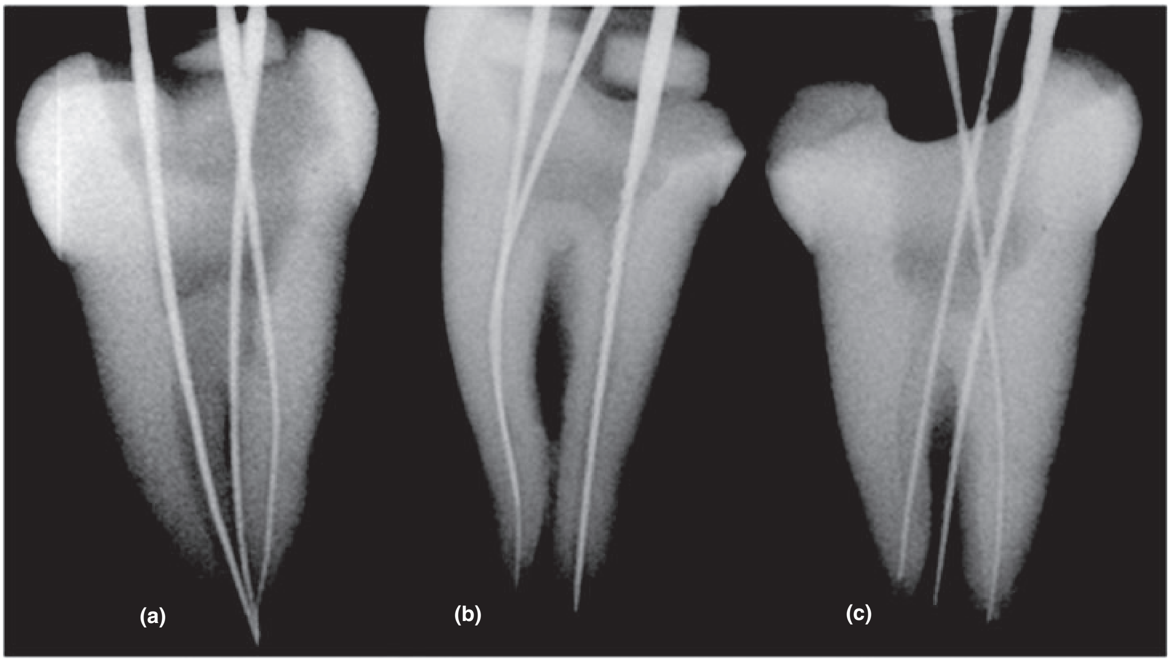

Figure 1 Classification of the Radiographic types. (a) type I; (b) type II; (c) type III.

the evaluation of the radiographic appearance was discussed until an agreement was reached, between ≥3 observers in accordance with the classification (Hörsted-Bindslev *et al.* 2007).

Root canal preparation and filling

The working length of each canal was established by measuring the penetration of a size 15 K-file (Flexofile, Dentsply Maillefer, Ballaigues, Switzerland) until it reached the apical foramen, and then subtracting 1 mm. The canals were prepared with the ProTaper Nickel-Titanium Rotary System (Dentsply Maillefer). The handpiece was used with an electric motor (X-Smart, Dentsply Maillefer) at 250 rpm. Instrumentation started with S1 up to the length corresponding to beginning of the root curvature. The SX instrument was used in a similar manner at the same length. Instrumentation was completed with S1, S2, F1 and F2 instruments to working length. Additional enlargement was completed with nickel titanium hand files, with the mesial canals to a size 40 K-file and distal canals to a size 50 K-file (Nitiflex-Dentsply Maillefer) using the balanced force technique (Roane *et al.* 1985). One percent sodium hypochlorite (Biodinâmica, Ibipora, PR, Brazil) was used continuously during root canal shaping, 2 mL for each file used; 0.5 mL of 17% EDTA (Biodinâmica) was used at the end of the biomechanical preparation for 1 min and a final rinse of sodium hypochlorite was performed.

Root canals were filled using a modified technique of the MicroSeal system (Maggiore 2004). The first step of the procedure was the selection of the correct master cone (Dentsply Maillefer) and its adjustment to achieve tug-back, 0.5 to 1 mm short of the working length. Sealer 26 (Dentsply, Petrópolis, RJ, Brazil) was placed into the canal with the master point and the sealer-coated master gutta-percha point was seated. A size B precurved finger spreader (Dentsply Maillefer) was inserted along the master point at the appropriate length for compaction. Initial lateral compaction was done with one or two size 20, .02 taper accessory points (Dentsply Maillefer) as suggested by Maggiore (2004). The spreader was reinserted and an appropriate compactor was coated with a uniform layer of material of the heated gutta-percha cartridge (Microflow/Analytic, Glendora, CA, USA) based on the manufacturer's instruction. A coated gutta-percha compactor was then carried immediately to the void previously created in the canal by the spreader and was placed as close to the working length as possible. With the application of a resisting force to the compactor's backing-out motion but without any apical pressure, the rotation of the compactor began at a speed of

5000 rpm (Davalou *et al.* 1999, Cathro & Love 2003, Gençoğlu 2003). After approximately 2 s, the compactor was removed slowly whilst being pushed softly against one side of the canal. Rotation did not stop until the compactor was removed from the canal (Gençoğlu 2003). Mild pressure was then applied in apical direction (vertical compaction) with a number 2 Paiva plugger (Golgran Indústria e Comércio de Instrumentos Odontológicos Ltda., Pirituba, Brazil), followed by a reinsertion of the spreader. If the first step did not fill the canal completely, the compactor was coated with a further increment of α gutta-percha and the procedure repeated. The access cavity was cleaned by removing excess gutta-percha and sealer and two radiographs were taken in orthoradial and proximal view. All clinical procedures were performed by the same investigator.

Sectioning and image analysis

Filled roots were stored in 100% humidity at 37 °C for 1 week. For each specimen, the root canal system from the canal orifice to the apex was divided into three levels: apical, middle and coronal. Horizontal sections at intervals of 600 μm were prepared beginning 1 mm from the apex until the subpulpal floor level, using a 0.3 mm Isomet saw (Isomet, Buehler, IL, USA) at the lowest speed setting (200 rpm) and continuous water cooling (5 °C) to prevent frictional heat. With this procedure, 10 to 14 slices per specimen were obtained and the sections were categorized for each root canal level since the length of the root canal was not identical in all the cases (See Fig. 2).

A Stereomicroscope Leica MZ 6 (Leica Microsystems GmbH, Wetzlar, Germany) with a digital camera was used to take photographs at 20× magnification in order to perform the image analyses. A millimetre ruler was also photographed with the sections to verify constant magnification and to facilitate the measurements. Images were transferred to a PC as an uncompressed JPEG file.

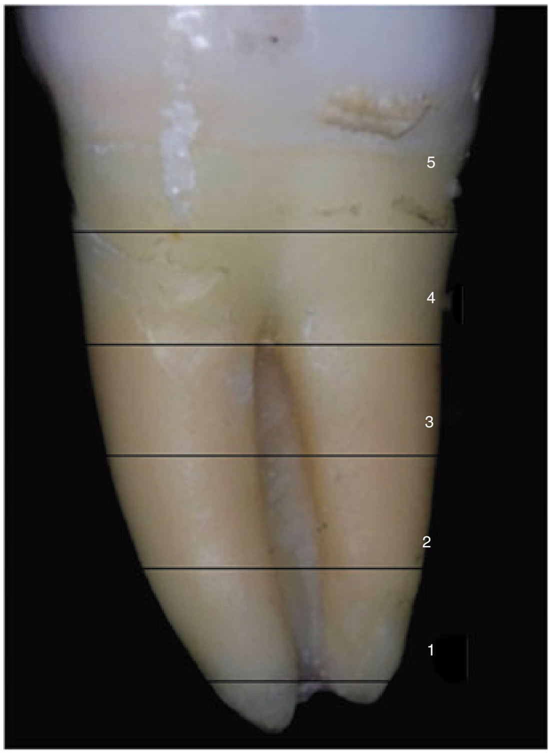

Figure 2 Represents the levels used to characterize the apical thirds, line 1: apical 1 mm, line 2: apical ¼, line 3: middle, line 4: coronal ¼, line 5: subpulpal floor level. Apical third (between lines 1 and 2), middle third (between lines 2 and 3) and coronal third (between lines 3 and 4).

The canal configuration was classified into the following categories, which was a modification of Melton's method (Fan *et al.* 2004a):

Category 1 (C1): an uninterrupted C-shape with no separation or division (see Fig. 3).

Category 2 (C2): the canal shape resembled a semicolon, resulting from a discontinuation of the C-shaped outline, but either angle α or β should be not less than 60°. These angles were measured using the Image Tool

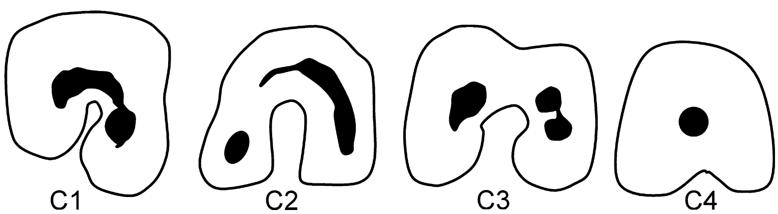

Figure 3 C-shaped canal configuration in four categories.

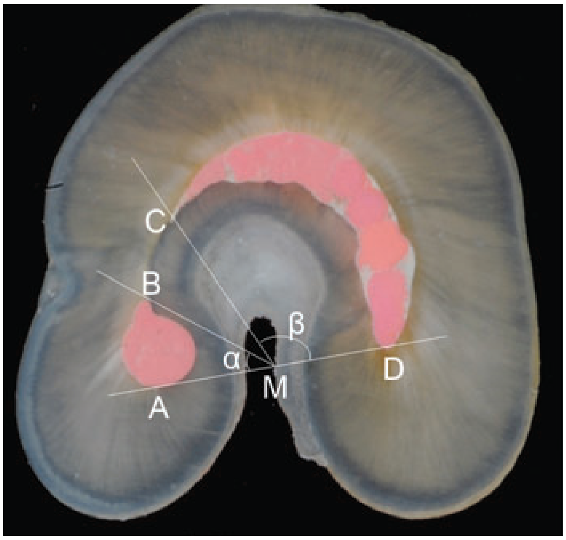

Figure 4 Measurement of angles for the C2 canal. Angle β is more than 60°. (A and B) Ends of one canal cross-section; (C and D) ends of the other canal cross-section; M, middle point of line AD; α, angle between line AM and line BM; β, angle between line CM and line DM.

software V.3 (University of Texas Health Science Center, San Antonio Dental School, San Antonio, TX, USA) (see Fig. 4).

Category 3 (C3): two or three separate canals and both angles, α and β, were less than 60°. The measuring method was the same as described above (see Fig. 5).

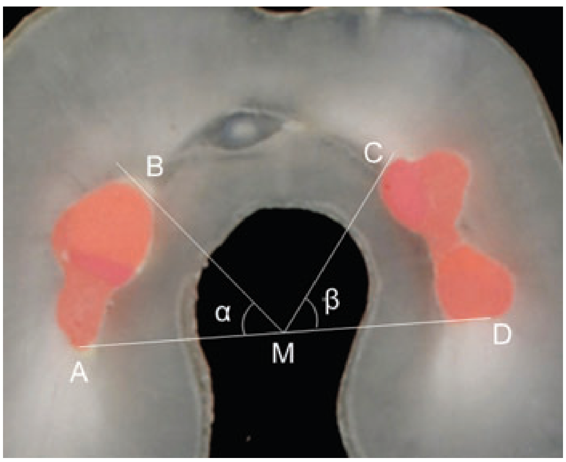

Figure 5 Measurement of angles for the C3 canal. Both angle α and angle β are less than 60°. (A and B) Ends of one canal cross-section; (C and D) ends of another canal cross-section; M, middle point of line AD; α, angle between line AM and line BM; β, angle between line CM and line DM.

Category 4 (C4): only one round or oval canal was present in that cross-section (see Fig. 3).

The area of the root canal and the gutta-percha on the coronal aspect of two representative sections from the apical, middle and coronal level (six sections for each evaluated tooth) was measured using the Image Tool software V.3 (UTHSCSA) and the percentage of gutta-percha area in each canal was then calculated. A representative section was defined as a section that had the most complex anatomy at the level evaluated. The order of complexity was established as C1 > C2 > C3 > C4. The measurements were repeated twice to ensure reproducibility.

Statistical significance for the mean of gutta-percha percentage area for each group of radiographic type (merging type, symmetrical or asymmetrical type) was determined for each level of the root canal using the Kruskal–Wallis test; the level of significance was set at $P < 0.05$; Similar statistical analyses were performed to determine any statistical significance of the mean of gutta-percha percentage for each root canal level.

A complementary analysis of the apical area was performed, the percentage of gutta-percha in the second to the fifth apical sections, approximately between the 1.6 and 3.4 mm from the apex, were analysed using the Kruskal–Wallis test with a level of significance of $P < 0.05$ to show any difference in the percentage of the gutta-percha area between the three configuration categories, C1, C2 and C3. The analyses of all the tests were performed by using the Graphpad in stat software (Graphpad, La Jolla, CA, USA).

Results

From the 23 teeth, seven were classified radiographically as type I, 9 as type II, and 7 as type III. In total, 138 sections were evaluated; 46 for each root level. All the teeth had at least one section with a C1, C2 or C3 canal anatomy. The gutta-percha could be seen as a pink coloured image and Sealer 26 as a white coloured image. The mean percentage of the gutta-percha area is described in the Table 1. No significant differences were found between the radiographic types concerning the percentage of gutta-percha area at any level. Analyses of the apical thirds showed that the gutta-percha area increased significantly in a coronal direction ($P < 0.05$) (See Table 1). The distribution of the radiographic types and the C-shaped canal configuration categories of the evaluated sections are presented in the Table 2.

The analysis of the apical area was performed on four sections of each of the relevant specimen to give a total

Table 1 Percentage of canal area filled by gutta-percha in the analysed sections by root canal level in the three radiographic types

Radiographic type	*n*	Apical			Middle			Coronal		
		Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
I	14	77.04	77.92	12.03	95.72	97.33	5.34	98.30	100	2.75
II	18	70.48	70.16	12.26	93.17	96.36	10.37	98.25	100	3.64
III	14	77.13	77.09	10.24	91.13	91.24	7.51	97.14	98.34	3.37
Total	46	74.5	76.36	11.81	93.32	95.88	8.27	97.92	100	3.27

SD, standard deviation.

Table 2 Distribution of radiographic types I–III and configuration categories C1–4 at three levels

	Apical					Middle					Coronal			
	C1	C2	C3	C4	Total	C1	C2	C3	C4	Total	C1	C2	C3	Total
Type I	11	0	0	3	14	8	0	5	1	14	11	0	3	14
Type II	5	8	5	0	18	0	9	9	0	18	4	8	6	18
Type III	7	3	4	0	14	5	7	2	0	14	6	7	1	14
Total	23	11	9	3	46	13	16	16	1	46	21	15	10	46

of 92. The distribution of the C-shaped canal configuration categories and the percentage of gutta-percha filled area of the apical sections (2nd to 5th) are presented in Table 3. No significant differences were found amongst the three categories. The C4 configuration category was not considered because it was present in only eight sections. Figures 6–9 illustrates the gutta-percha filled area in each radiographic type. Additional cases are presented as supporting information (Fig. S1).

Discussion

A C-shaped mandibular second molar tooth can exhibit multiple irregularities in their canal system and can vary from the canal orifice to the apex (Melton *et al.* 1991). The analysis presented in this study was based on a model introduced by Eguchi *et al.* (1985), which made it possible to quantify the area of gutta-percha within the C-shaped canals evaluated. The quality of a root filling evaluated by calculating the percentage of gutta-percha has been used to compare different obturation techniques (De-Deus *et al.* 2006).

Table 3 Apical third analysis of the apical sections (2nd to 5th) of the percentage of canal area filled by gutta-percha in the three configuration categories

Configuration categories	*n*	Mean	Median	SD
C1	35	72.64	75.00	14.36
C2	28	79.62	80.06	13.52
C3	21	73.51	65.04	17.01

SD, standard deviation.

Evaluation of the filling within C-shaped molar teeth presents two characteristics that can decrease the quantity of material obtained by the cross-sectional method. The first feature is that C-shaped molars have a deep pulp chamber floor, usually between 3 mm below the cementoenamel junction (Min *et al.* 2006) and the second one is the canal anatomy at the 1 mm level. The analysis of C-shaped roots requires the presence of mesial and distal canals in the same section. Differences in length between the mesial and distal foramina, presence of a single round or oval lumen, or no canal lumen explain why the 1 mm sections were excluded in the present study. Similar findings were observed by Fan *et al.* (2004b). For these reasons the selection of the sections in the preliminary analyses was performed for each root canal level (apical, middle and coronal) due to the difficultly in standardization of the root canal length between the samples.

In contrast with other studies that evaluated root canal filling techniques with a 1 mm interval (Cathro & Love 2003, Gençoğlu 2003), a number of modifications were included to reflect the anatomical complexity of the samples. Sections of 300 μm were selected in the attempt to provide a greater number of samples. The evaluation of serial cut sections avoids the omission of filling defects during the analytical process.

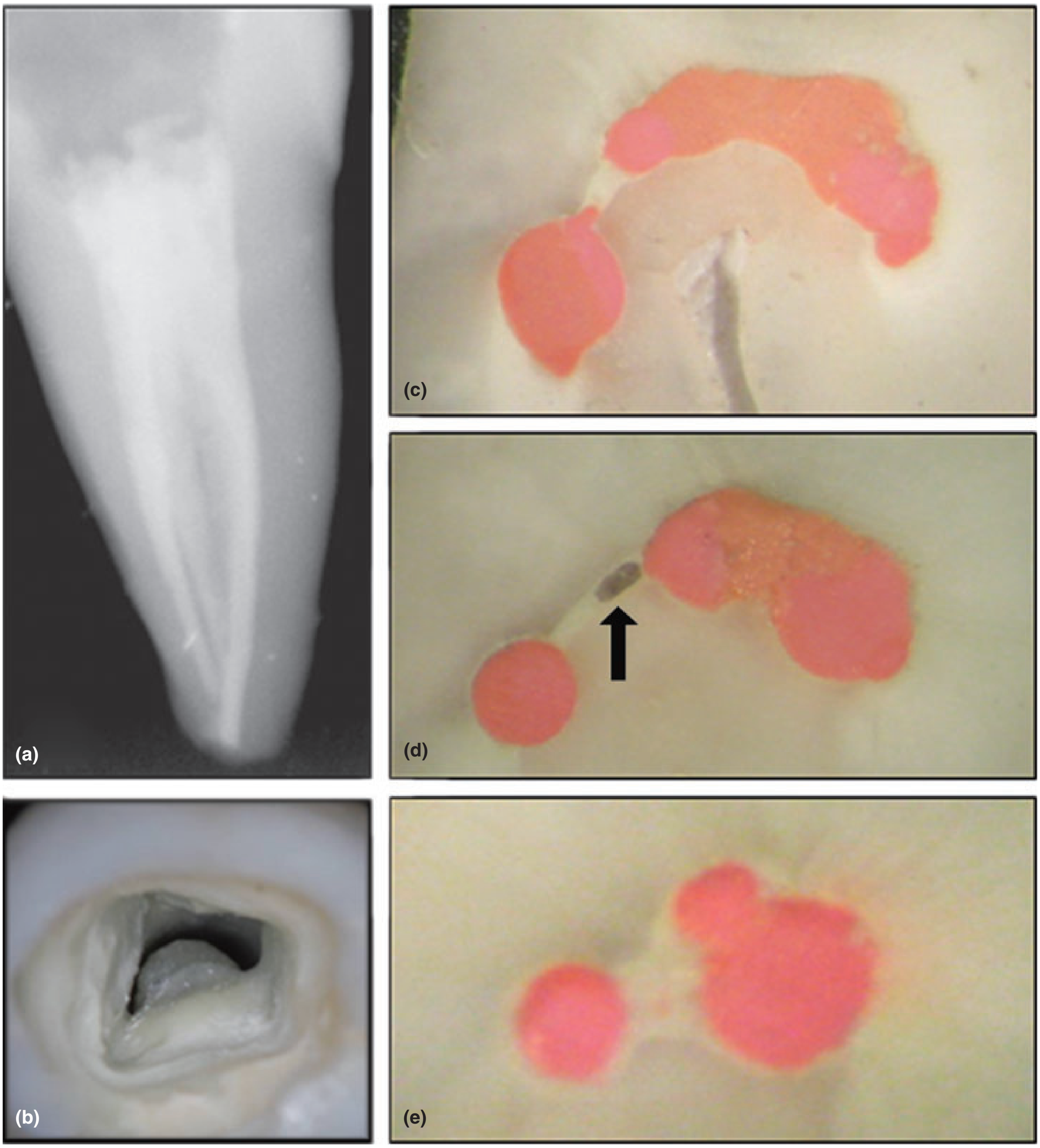

Figure 6 Radiograph of an obturated Merging type C-shaped molar (a); a complete C-shaped pulp chamber is shown in (b); a middle third C1 configuration shows good adaptation of the α and β gutta-percha in the distal and mesial canal (c). Apical section (d) shows a void (arrow). Increment of the sealer area is shown in a more apical level (e).

According to Maggiore (2004) the filling of irregular anatomy such as oval canals requires the use of accessory points before the use of the α gutta-percha of the MicroSeal system, with similar suggestions having been made for the Thermafil technique (Gutmann & Witherspoon 1998). Additionally vertical compaction was applied in order to obtain a better distribution of gutta-percha in the root canal. The use of the gutta-percha master point was based on the modified technique and according to the principle that the master

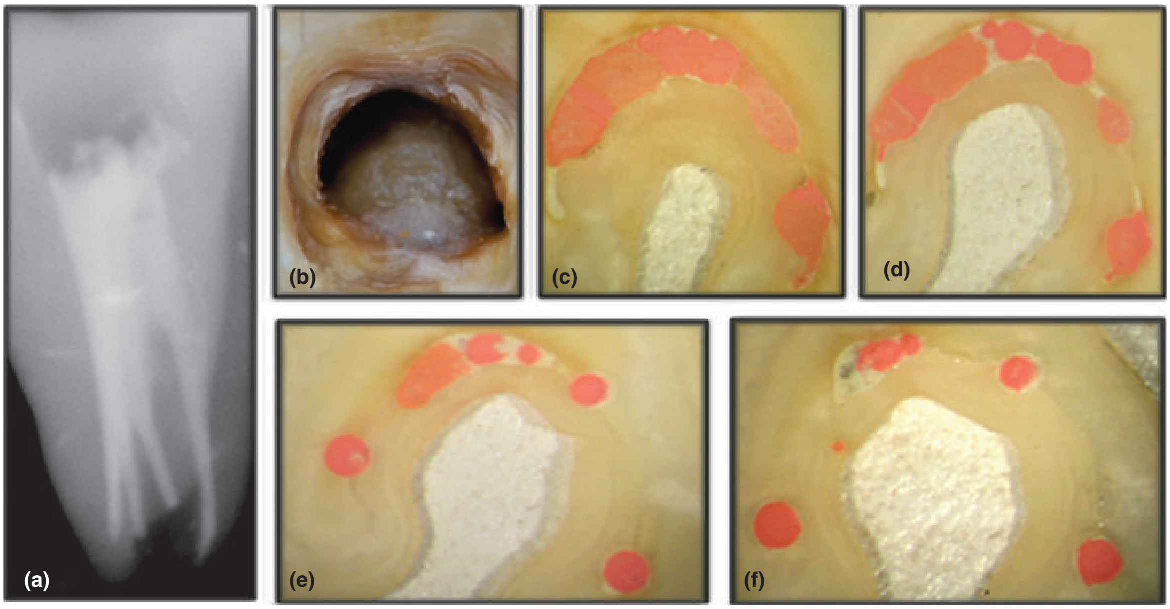

Figure 7 Proximal radiographic view of an obturated asymmetrical C-shaped molar (a). A complete C-shaped pulp chamber is shown in (b). Middle third section shows a good adaptation of the α and β gutta-percha in the distal canal and accessory points are visible in the large isthmus (c–d). Apical sections (e–f) show an increment in the sealer area; observe the division of the distal canal and the good adaptation of the root canal filling in the mesio-lingual canal.

point serves to avoid the possibility of apical extrusion of gutta-percha/sealer. In spite of the use of β gutta-percha in the master cone, good integration with the α gutta-percha of the MicroSeal system could be seen in the coronal and middle thirds (See Figs 6 and 7).

Instrumentation of the C-shaped canals was performed with the ProTaper system and the hand instruments used with the balanced forced technique. The use of a 0.25 mm or smaller diameter instrument could have left many areas without instrumentation. Cheung *et al.* (2007) stated that shortest and longest diameter of the apical constriction of mesial canals in C-shaped molars were found to be 0.15–0.26 mm and 0.22 and 0.36 mm for the distal canal. If it is assumed that C-shaped canals present one or more isthmuses in the apical third, the use of smaller diameters such as 0.25 or 0.30 can make the cleaning, shaping and filling of these root canals difficult.

Despite the fact that radiographs provide two-dimensional images, information gleaned from them may be beneficial in determining the nature of the root canal anatomy when a C-shaped configuration is suspected. Fan *et al.* (2004b) concluded that the transverse anatomy of a C-shaped canal system in mandibular second molar teeth might be predicted according to the radiographic appearance.

One of the purposes of this study was to determine if there was a relationship between the gutta-percha cross-sectional area and the radiographic categorization of the C-shaped molars. Fan *et al.* (2004b) reported that C1 and C2 canals are more prevalent in the apical and middle third of merging and asymmetrical radiographic types. Therefore, it was expected that the radiographic symmetrical type would present a greater gutta-percha area in comparison to the other C-shaped radiographic types.

Despite the low number of samples and the absence of a statistically significant difference amongst the three radiographic types, certain noncontrolled variables can influence the area of gutta-percha in the canal. These variables can be used as evaluative criteria in future studies: C2 canals were highly variable; for instance, a C2 canal with a 60° angle could be less difficult to fill than a 120° or 150° C2 canal. Another observation concerns the length and the width of the isthmus between the mesial and distal main canals, especially in C1 and C2 canals. A larger isthmus is more difficult to fill than a shorter isthmus and a wider isthmus requires more gutta-percha than a thinner one. Distal and mesial canals of the C3 canal system have the shape of large oval canals. Another uncontrolled variable was the difficulty in passing an endodontic instrument

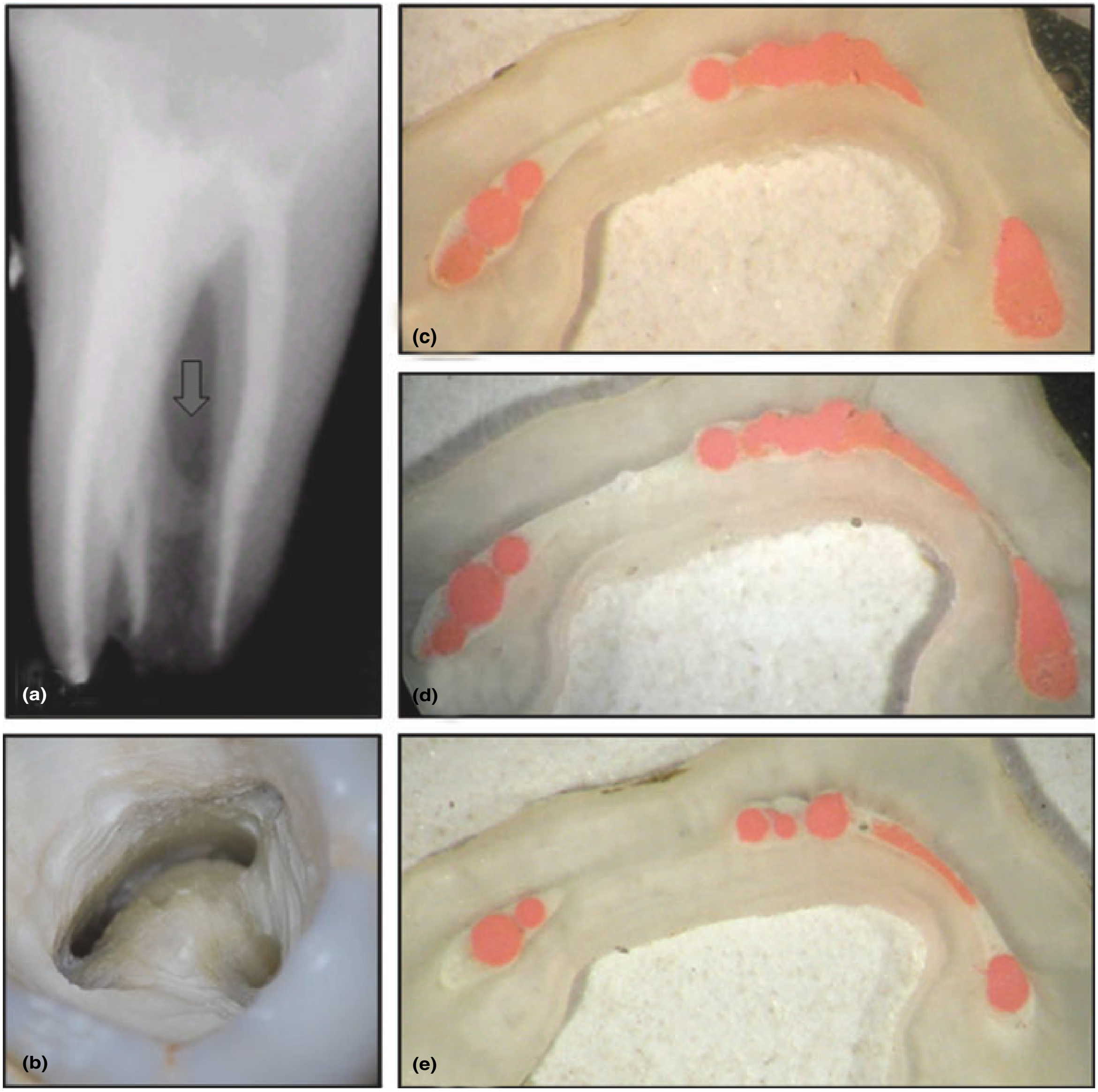

Figure 8 The radiograph in (a) shows a complex root canal system with evidence of communication between the middle and apical third (arrow); three sections at this level (c–e) show the transition of the root canal anatomy from a C2 large distal canal with an isolated mesio-lingual canal (c) to a C1 canal configuration (d). A large mesial canal can be seen in (e) gutta-percha is evident in the isthmus; distal canal is seen as an oval canal with a decrease of gutta-percha area. An incomplete C-shaped pulp chamber is shown in (b).

between the mesio-buccal and distal canal. According to Fan *et al.* (2004a), and Seo & Park (2004), the canal shape in the middle and apical third of C-shaped canal systems could not be predicted on the basis of the shape at the orifice. (See Fig 9).

The similar distribution of these anatomical noncontrolled variables in the samples studied seems to be the reason for the nonstatistical significance between the radiographic types. This fact was confirmed in the analysis of the gutta-percha area in the different C-shaped canal configurations (C1, C2 and C3) in which no statistical differences were noted.

In the present study, a decrease of gutta-percha in the apical sections in comparison with middle and

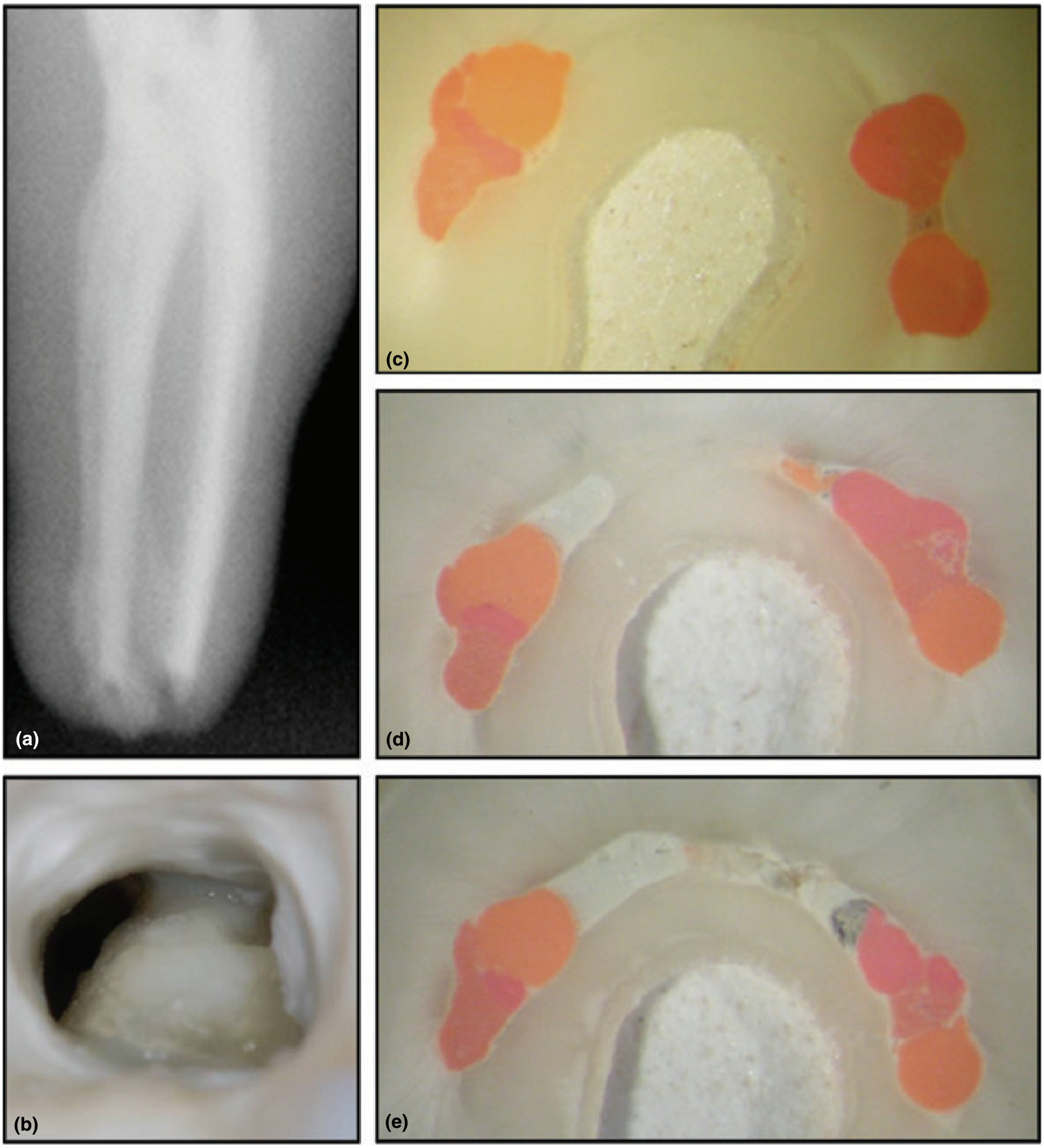

Figure 9 The difficult to cross an endodontic instrument between the mesio-buccal and distal canal and the impact in the root canal filling is showed in the following case. Radiograph in (a) shows a C-shaped symmetrical type canal. An incomplete C-shaped pulp chamber is shown in (b). C3 canal configuration can be seen in the coronal section (c). Confluence of the mesial and distal canals is seen in (d). C1 canal configuration is evident in the apical section (e). Gutta-percha is absent in the isthmuses that are partially filled with sealer and debris.

coronal sections was significant. The apical anatomy often influences the area of the gutta-percha in fillings. The difficulty in filling irregular canals was confirmed by other investigations in less complex root canal systems such as oval canals (Wu & Wesselink 2001, Wu *et al.* 2002). De-Deus *et al.* (2008) found that the percentage of the canal filled area with gutta-percha and sealer in mandibular incisors with oval canals at the 5 mm level was 70.15% for the System B obturation technique and 78.31% for the Thermafil technique. In the present study, a mean of 74.5% was found at the apical level (See Table 1). Many variables such as the irregular distribution of the different anatomical types through the length of the canal of the samples (Manning 1990, Seo & Park 2004, Cheung *et al.* 2007) could be responsible for the decrease of the quality of the filling in this anatomical variation, which would affect not only the MicroSeal system, but also in other thermoplastic gutta-percha filling systems.

Conclusion

The percentage of area filled with gutta-percha was similar in the three radiographic types and canal configuration categories of C-shaped root canal systems of mandibular second molars; the percentage of the gutta-percha filled area was lower in the apical third. These results reflect the difficulty of achieving predictable filling of the root canal system when this anatomical variation exists.

Acknowledgements

Text extracts from Fan *et al.* (2004a, 2007) and Figs 4 and 5 were modified or reproduced with permission from Elsevier.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1. Two C-shaped molars with a C1 configuration in the coronal (B–E) and apical sections (C–F). Radiographs in (A–D) show the presence of the root filling material in the complex mesiobuccal-distal canal. Increase in the sealer area is evident in the apical sections; an isthmus filled with gutta-percha can be seen in the mesial canal (C).

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