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Analysis of four gutta-percha techniques used to fill mesial root canals of mandibular molars

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Abstract

Marciano MA, Ordinola-Zapata R, Cunha TVRN, Duarte MAH, Cavenago BC, Garcia RB, Bramante CM, Bernardineli N, Moraes IG. Analysis of four gutta-percha techniques used to fill mesial root canals of mandibular molars. *International Endodontic Journal*, **44**, 321–329, 2011.

Aim To compare the percentage of gutta-percha, sealer and voids and the influence of isthmuses in mesial root canals of mandibular molars filled with different techniques.

Methodology Canals in 60 mesial roots of mandibular first molars were prepared with ProTaper instruments to size F2 (size 25, 0.08 taper) and filled using a single-cone, lateral compaction, System B or Thermafil techniques. An epoxy resin sealer was labelled with Rhodamine-B dye to allow analysis under a confocal microscope. The percentage of gutta-percha, sealer and area of voids was calculated at 2, 4 and 6 mm from the apex, using Image Tool 3.0 software. Statistical analysis was performed using nonparametric Kruskal–Wallis and Dunn tests ($P < 0.05$). The influence of isthmuses on the presence or absence of voids was evaluated using the Fisher test.

Results At the 2 mm level, the percentage of gutta-percha, sealer and voids was similar amongst the System B, lateral compaction and single-cone techniques. The single-cone technique revealed significantly less gutta-percha, more sealer and voids in comparison with the Thermafil technique at the 2 and 4 mm level ($P < 0.05$). The analysis of all sections (2, 4 and 6 mm) revealed that more gutta-percha and less sealer and voids were found in root canals filled with Thermafil and System B techniques ($P < 0.05$). The Fisher test revealed that the presence of isthmuses increased the occurence of voids in the lateral compaction group only ($P < 0.05$).

Conclusion Gutta-percha, sealer filled area and voids were dependent on the canal-filling technique. The presence of isthmuses may influence the quality of root filling.

Keywords: confocal microscopy, dental anatomy, epoxy resin sealers, gutta-percha filled area, mandibular molars.

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Introduction

The filling of the cleaned root canal must accomplish a high level of adaptability to the root canal space including accessory anatomy. For research purposes, single-rooted teeth are commonly used to compare different filling techniques (Gençoglu *et al.* 2002). From a methodological perspective, standardization of the specimens is often necessary for comparative purposes, avoiding anatomical irregularities and consequently, improving the statistical analyses. However, a disadvantage is that it could limit the relevance of the results because clinicians confront a variety of anatomical irregularities that may not be represented in the specimens selected. Irregular anatomy including

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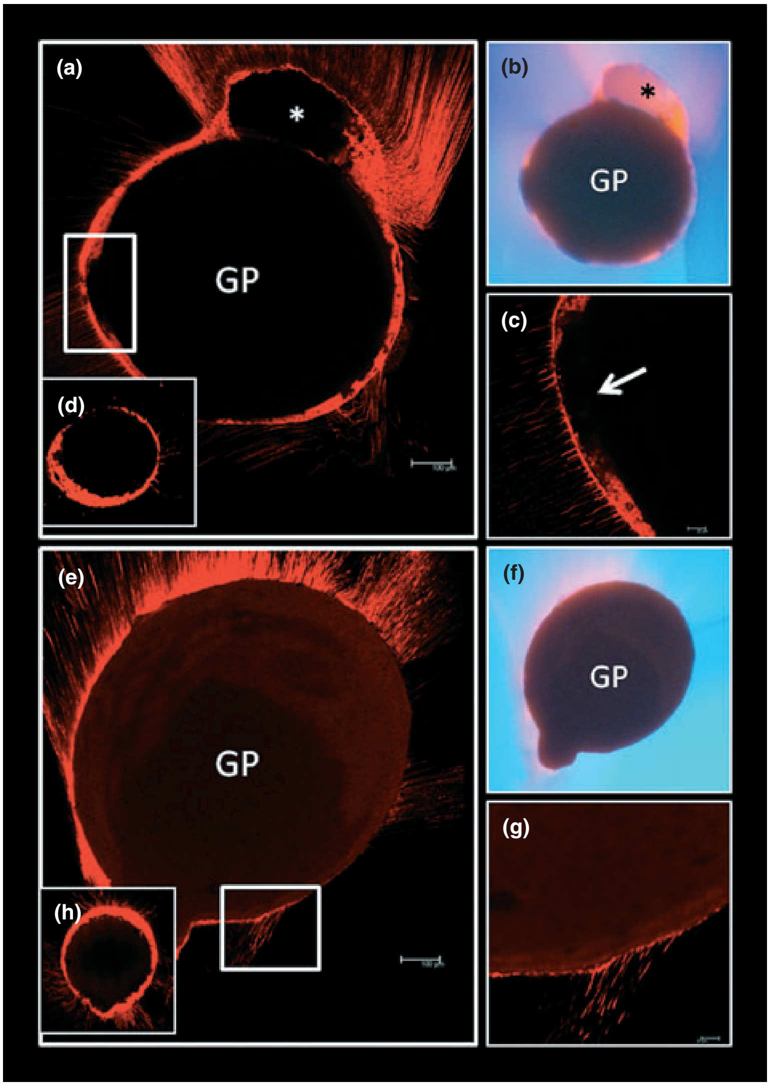

Figure 1 (a–d) Representative pictures of a canal filled with the single-cone technique at the 6 mm level. Bar represents 100 μm. An evident void (*) can be confirmed in the epifluorescence image (b). A magnification of the interface can be seen in (c), a gap is visible (arrow). Bar represents 20 μm. A representative 2-mm section of the single-cone technique is seen in (d). (e–h) Representative picture of a canal filled with System B technique at the 6 mm level. An adequate adaptation of the gutta-percha to the root canal walls can be observed in epifluorescence and confocal images. Bar represents 100 μm (g). The magnification of the interface confirms the adaptation. Bar represents 20 μm. No voids were found in this canal. Representative 2-mm level section of System B technique can be seen in (h).

isthmuses are usually found in all types of roots in which two canals are present, such as the mesial roots of mandibular molars; such system cannot be cleaned by root canal instruments (Mannocci *et al.* 2005, Nair *et al.* 2005, Carr *et al.* 2009). The incidence of isthmuses has been reported to be 54–89% in mesial roots of first mandibular molars (Gu *et al.* 2009) and is more frequent 3–6 mm from the apex (Jung *et al.* 2005).

Accumulation of debris in isthmuses and ramifications could be critical (Paque *et al.* 2009). In fact, Von Arx (2005) reported in a clinical study the presence of unfilled isthmuses in mandibular first molars with unsuccessful endodontic treatment. The author stated that none of the canal isthmuses had been filled by the previous orthograde root canal treatment. In another clinical study, Nair *et al.* (2005) found bacteria and biofilms in unfilled isthmuses of mandibular molars

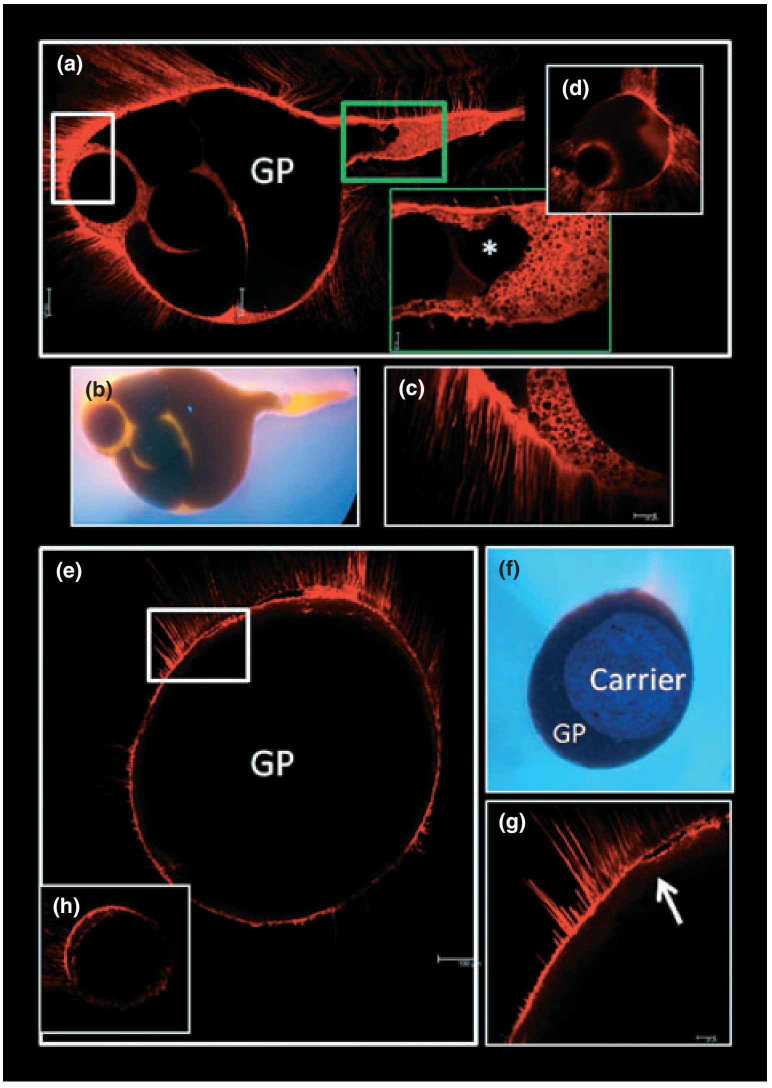

Figure 2 (a–d), Representative pictures of a canal filled with the lateral compaction technique at the 6 mm level. The presence of master and accessory gutta-percha cones can be observed in confocal and epifluorescence images. Bar represents 100 μm. The presence of a void can be observed in detail (*). (c) A magnification of root canal walls in which the adaptation of gutta-percha and sealer to the root canal walls can be observed. (d) Representative section of 2 mm level with adequate adaptation of the gutta-percha cones. Representative picture of a canal filled with the Thermafil technique. Bar represents 100 μm (e–h). In overall, satisfactory adaptation of the gutta-percha to the root canal walls is observed. However, a magnification of the sealer/dentin interface shows a minimal gap (<10 μm) between the gutta-percha/sealer and the root canal walls (arrow) (g). This gap cannot be observed easily in the epifluorescence image (f), showing the advantages of high-contrast confocal images to identify the presence of small gaps. Representative 2-mm level section of the Thermafil technique can be seen in (h).

that were treated with a manual or rotary instruments system, 5.25% sodium hypochlorite and filled with the lateral compaction technique.

Adaptation of filling materials to canal walls in mandibular molars using different techniques has been addressed in two previous studies that used cross-sections of roots (Ardila *et al.* 2003, Weis *et al.* 2004). These studies considered canal isthmuses during the evaluation, but no data on the percentage of gutta-percha were described. De-Deus *et al.* (2007) used mandibular molars to evaluate the System B and Thermafil techniques but only mesio-bucal root canals

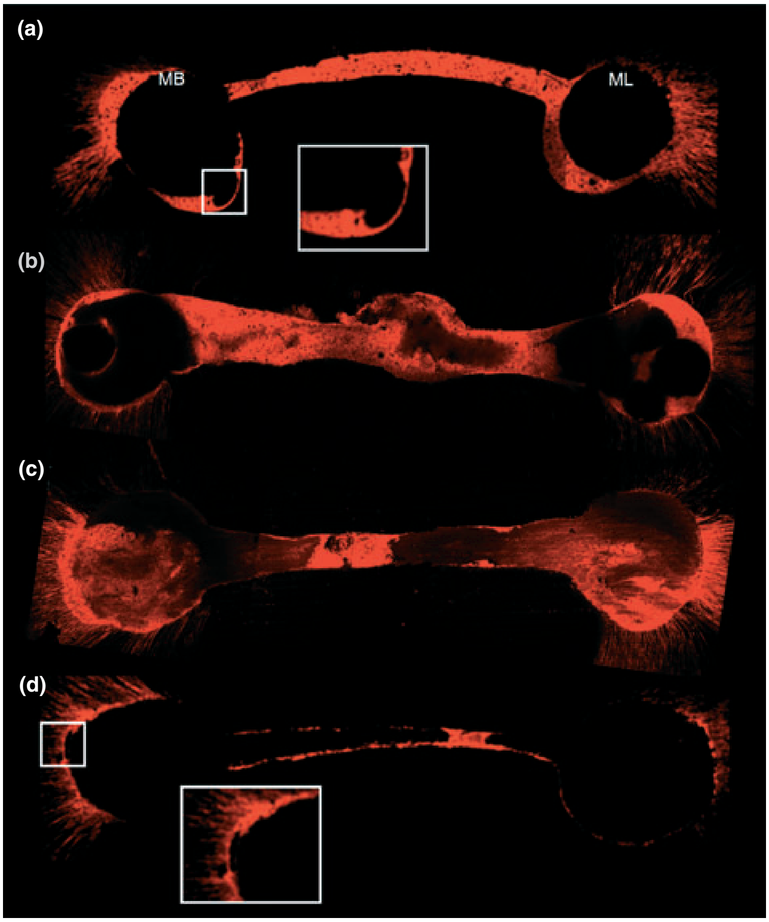

Figure 3 Representative ×100 pictures of 4 mm level sections of canals filled with the single-cone technique (a), lateral compaction (b), System B (c) and Thermafil (d). The magnification of image (a) showed an evident void, also observed in image (d). The ability of sealer to penetrate into the cleaned isthmuses can be observed in all the evaluated techniques. Gutta-percha filling the isthmuses can be observed in the System B and Thermafil groups. Confocal pictures showed that the instrumentation process did not affect a great percentage of root canal walls especially at 4 and 6 mm level.

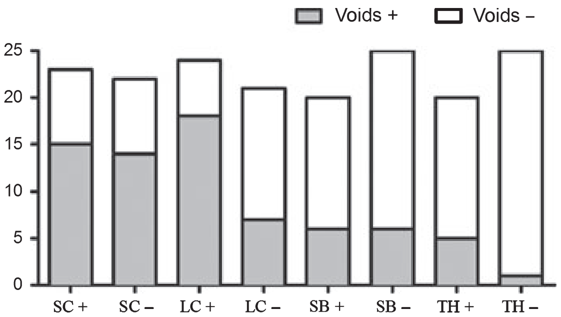

Figure 4 Presence of voids in all the evaluated sections in the presence (+) or absence (–) of isthmuses after the use of single-cone, lateral compaction, System B and Thermafil techniques. The presence of isthmuses increased the presence of voids only in lateral compaction group ($P < 0.05$).

were selected for the analysis, given the inherent variability of the internal anatomy of mandibular molars, it would be useful to know whether the most simple filling techniques such as single cone or Thermafil Obturators perform in a similar manner to lateral compaction or System B techniques that require more enhanced clinical skills.

In this study, the hypotheses tested were that the quality of the filling in mesial canals of mandibular molars is dependent on the type of filling technique. Thus, the aim was to compare the percentage of gutta-percha, sealer and voids in mesial root canals of mandibular molars filled with the following techniques: single-cone, lateral compaction, System B and Thermafil using epifluorescence and confocal laser scanning microscopy (CLSM). The presence or absence of voids and the influence of isthmuses on the related parameters were also evaluated.

Material and methods

Collection of teeth

Sixty extracted first mandibular molar teeth with patent mesial canals were selected. The ethics committee of the institution in which the study was carried out approved the use of extracted teeth for research purposes (CEP 122-2009). The length of the selected teeth was between 19 and 21 mm, and all root canals with a curvature between 15° and 30° according to Schneider (1971) were included. Periapical radiographs of each tooth were taken to confirm two mesial canals with separate foramina.

Root canal preparation and filling

Conventional access to the root canal system was performed using high-speed diamond burs 1014 (Sorensen, SP, Brazil). The working length was established measuring the position of a size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) when it reached the apical foramen and then subtracting 0.5 mm. Then, the mesial canals were negotiated a size 20 K-file. The root canals were shaped using the ProTaper rotary system (Dentsply Maillefer). A contra-angle handpiece was used with an electric motor (X-Smart; Dentsply Maillefer) at 250 rpm. The S1 instrument was used at the coronal and middle third, the SX instrument was used to increase the taper of the coronal third and S1, S2, F1 and F2 size 25, 0.08 taper were used sequentially to the full working length. Then, the end-point of preparation was confirmed to be 0.25 mm after gauging with a size 25 K-file. The specimens in which the size 25 K-file exceeded the diameter of the apical foramen were discarded and replaced with another specimen. Because the F2 finishing file was used 0.5 mm from the foramen, a diameter of 0.30 mm was confirmed using a size 30 K-file 1 mm short of the foramen and a size 35 NitiFlex file (Dentsply Maillefer) at 1.5 mm from the foramen. After the use of each hand file or rotary instrument, 2 mL of 2.5% sodium hypochlorite (NaOCl) was used to irrigate the canal. After instrumentation, the canals were irrigated with 2 mL of 2.5% NaOCl for 1 min using passive ultrasonic irrigation with an intermittent flush technique; this procedure was repeated three times (van der Sluis *et al.* 2007) using an ultrasonic unit (Jet-Sonic Four Plus; Gnatus, Ribeirão Preto, SP, Brazil) set to the *Endo* mode. Then, the root canals received a final flush of 2 mL of 17% EDTA (pH 7.7) for 3 min. Finally, the canals were washed with 2 mL of distilled water and dried with paper points (Dentsply Maillefer).

Specimens were randomly divided in four groups ($n = 15$) using an open source random number generator (Openepi random program) available at: http://www.openepi.com/Menu/OpenEpiMenu.htm. G1: single cone, G2: lateral compaction, G3: System B (Elements Obturation Unit; SybronEndo, Orange, CA, USA) and G4: Thermafil System (Dentsply Tulsa Dental, Tulsa, OK, USA). For filling procedures, 2 cm of each paste a and b of the epoxy resin sealer ThermaSeal Plus (Dentsply Tulsa Dental) was used in every root (approximately 0.05 mL). To facilitate fluorescence under the confocal laser scanning microscope, the sealer was mixed with fluorescent Rhodamine dye to an approximate concentration of 0.1% (D'Alpino *et al.* 2006; Ordinola-Zapata *et al.* 2009a). The Rhodamine-sealer mixture was thoroughly applied into the root canal with a size 30 lentulo spiral (Dentsply Maillefer) keeping the instrument 2 mm from the apex.

Group 1: Single cone

A F2 gutta-percha cone (ProTaper; Dentsply Maillefer) with tug-back was selected. The cone was coated with sealer and inserted into the canal until working length. Excess material was seared off and condensed with a plugger 1 mm below the canal orifice.

Group 2: Lateral compaction

The ability of a size 30, 0.02 taper gutta-percha cone (Dentsply Maillefer) to reach 1 mm from the foramen was confirmed. The master cone was coated with sealer and inserted into the canal. The root canals were filled with the lateral compaction technique using a precurved size B endodontic finger spreader (Dentsply Maillefer) inserted 2 mm short of the working length. Five to eight accessory gutta-percha points size 20, 0.02 taper (Dentsply Maillefer) were used until the entire length of the root canal was filled.

Group 3: System B Elements obturation unit

A F2 gutta-percha cone (Dentsply Maillefer) with tug-back was selected. The master cone was coated with sealer and inserted into the root canal in the same manner described for groups 1 and 2. A System B plugger (SybronEndo) set at 200 °C was used to cut the gutta-percha cone at the orifice level. Buchanan hand pluggers (SybronEndo) were used to adapt the gutta-percha at the orifice level. Then, the downpack procedure was performed introducing a 0.06 taper System B plugger in a continuous wave of condensation within 4 mm of working length. The plugger was held in position for 10 s before the System B was activated for 1 s and withdrawn from the tooth. Gutta-percha at the apical level was condensed using Buchanan hand pluggers (SybronEndo). The backfill of the coronal portion was achieved using the extruder handpiece and 23-gauge needle tips containing gutta-percha at a temperature of 200 °C and condensed with the appropriated hand pluggers (SybronEndo).

Group 4: Thermafil

Prepared roots were filled using the Thermafil System (Dentsply Tulsa Dental). The Thermafil Obturator size 30 was used as determined with a Thermafil 30 verifier. Plastic verifiers without gutta-percha were also confirmed to fit 1 mm from the WL. Then, the Obturators were heated in a ThermaPrep Plus oven (Dentsply Tulsa Dental). The Thermafil Obturator was inserted slowly into the canal previously filled with the sealer until it reached its final position. The ProTaper Thermafil Obturators were not used as they were not available when the study was performed. In all the groups, a single operator performed all the clinical procedures.

Sectioning and CLSM analysis

Filled roots were stored in 100% humidity at 37 °C for 1 week to allow setting of the sealer. The specimens were sectioned horizontally at 2, 4 and 6 mm from the apex using a 0.3 mm Isomet saw (Isomet; Buehler, Lake Bluff, IL, USA) at 200 rpm and continuous water cooling to prevent frictional heat. Then, the surfaces were polished using sandpaper under running water to eliminate debris from the cutting procedure (Politriz; Arotec, Cotia, SP, Brazil).

Confocal laser scanning microscopy and epifluorescence images were recorded at 100× using a Leica TCS-SPE confocal microscope (Leica Microsystems GmbH, Mannheim, Germany). Confocal images were used to measure the sealer distribution in mm^2. Epifluorescent images were used to identify voids in the mass of the filling. Once the voids were identified, the sum of the sealer and the voids area was subtracted from the total canal area; consequently, the gutta-percha filled area was obtained. The area in mm^2 corresponding to the root canal area was measured, including the two mesial canals and the isthmus if present. Image analysis was performed using the Image Tool 3.0 software (UTHSCSA, San Antonio, TX, USA). Then, the percentages of gutta-percha, sealer and voids in each section were calculated. The measurements were repeated two times to ensure reproducibility. The presence of isthmuses and voids at the levels studied was also registered as positive or negative.

Statistical analysis was performed using the non-parametric Kruskal–Wallis and Dunn tests ($P < 0.05$) as a result of the absence of normal distribution confirmed in preliminary analysis. The presence or absence of isthmuses and voids in each section was evaluated using the chi-squared and the Fisher test. The influence of the presence or absence of isthmuses on the percentage of gutta-percha and sealer area in all the studied sections was evaluated using the Mann–Whitney *U*-test. The relationship between the presence/absence of isthmus and voids in all the studied sections was evaluated using the chi-squared and the Fisher test. The analyses of all the tests were performed by using the GraphPad Prism software (Graphpad, La Jolla, CA, USA).

Results

From 60 teeth, 180 sections were evaluated. No significant differences were found amongst the groups for the presence of isthmuses (See Table 1) or post-instrumentation canal area and in all the evaluated levels ($P > 0.05$). See Tables 2–4. The median and range of the percentage of the evaluated criteria are shown in Tables 2–5. The results in terms of percentages at the 2 mm level revealed that the gutta-percha, sealer and voids area were similar amongst the System B, lateral compaction and single-cone techniques. Also, the single-cone technique had significantly less gutta-percha, more sealer and void percentage in comparison with the Thermafil technique at the 2 and 4 mm level ($P < 0.05$). At the 6 mm level, Thermafil and System B had more gutta-percha, less sealer and voids percentages than lateral compaction and single-cone techniques.

Table 1 Presence of isthmuses in the evaluated samples

Level	Thermafil	System B	Lateral compaction	Single cone	Statistical differences
2 mm	2	2	2	4	NS
4 mm	9	10	12	10	NS
6 mm	10	8	10	9	NS
Total	21	20	24	23	NS

NS, no statistical differences.

Table 2 Area (mm^2) and percentage (%) of canal, gutta-percha (GP), sealer and voids at the 2 mm level

Group	Canal area	GP area	GP (%)	Sealer area	Sealer (%)	Voids presence	Voids (%)
Thermafil	0.41[a]	0.27	82.2 (39.0–90.0)[a]	0.07	17.8 (10.0–61.5)[a]	0/15[a]	0.0 (0)[a]
System B	0.40[a]	0.3	77.6 (51.8–89.3)[ab]	0.1	22.3 (10.7–41.1)[ab]	4/15[ab]	0.0 (0–9.5)[ab]
Lateral compaction	0.34[a]	0.22	63.1 (43.2–94.1)[b]	0.1	31.9 (5.8–56.8)[ab]	4/15[ab]	0.0 (0–13.8)[ab]
Single cone	0.43[a]	0.19	61.3 (20.7–92.6)[b]	0.2	38.7 (0.5–75.8)[b]	9/15[b]	2.27 (0–7.4)[b]

Values represent median and range. Different letter in each column indicates statistically significant differences ($P < 0.05$).

Table 3 Area (mm^2) and percentage (%) of canal, gutta-percha (GP), sealer and voids at the 4 mm level

Group	Canal area	GP area	GP (%)	Sealer area	Sealer (%)	Voids presence	Voids (%)
Thermafil	1.1[a]	0.9	82.5 (55.2–90.8)[a]	0.1	17.2 (9.2–44.2)[a]	3/15[a]	0.0 (0–1.6)[a]
System B	0.9[a]	0.7	75.5 (46.6–92.3)[ab]	0.2	22.5 (7.7–49.1)[ab]	5/15[ab]	0.0 (0–18.2)[ab]
Lateral compaction	0.8[a]	0.5	63.8 (44.5–85)[b]	0.3	31.4 (15–55.5)[b]	11/15[b]	1.56 (0–6)[b]
Single cone	0.9[a]	0.5	56.8 (27.9–85.2)[b]	0.3	40.7 (12.9–67.8)[b]	11/15[b]	1.8 (0–30.3)[b]

Values represent median and range. Different letter in each column indicates statistically significant differences ($P < 0.05$).

Table 4 Area (mm^2) and percentage (%) of canal, gutta-percha (GP), sealer and voids at the 6 mm level

Group	Canal area	GP area	GP (%)	Sealer area	Sealer (%)	Voids presence	Voids (%)
Thermafil	1.4[a]	1.0	87.8 (41.1–93.5)[a]	0.1	12.5 (8.4–36.9)[a]	3/15[b]	0.0 (0–0.8)[a]
System B	1.2[a]	1.0	86.2 (63.1–94.3)[a]	0.1	12.0 (5.7–58.1)[a]	3/15[b]	0.0 (0–0.8)[a]
Lateral compaction	1.3[a]	0.8	68 (54.8–88.4)[b]	0.3	31.5 (11.6–45.2)[b]	10/15[a]	1.3 (0–3.8)[b]
Single cone	1.4[a]	0.7	65.3 (36.2–93.7)[b]	0.5	33.0 (6.2–58.4)[b]	9/15[a]	0.7 (0–9.3)[ab]

Values represent median and range. Different letter in each column indicates statistically significant differences ($P < 0.05$).

Table 5 Percentage of total canal area of gutta-percha (GP), sealer and sections with voids at all the evaluated levels

Group	GP (%)	Sealer (%)	Voids presence	Voids (%)
Thermafil	84.9 (38.5–93.5)[a]	16.7 (8.4–61.5)[a]	6/45[a]	0.0 (0–1.5)[a]
System B	78.3 (46.7–94.3)[a]	20.7 (5.7–58.1)[a]	12/45[a]	0.0 (0–18.2)[ab]
Lateral compaction	63.8 (43.2–94.1)[b]	31.6 (5.9–56.8)[b]	25/45[b]	1.2 (0–13.9)[bc]
Single cone	59.4 (20.7–93.7)[b]	38.7 (0.5–75.8)[b]	29/45[b]	1.7 (0–30.3)[c]

Values represent median and range. Different letter in each column indicates statistically significant differences ($P < 0.05$).

Table 6 Percentage of gutta-percha (GP) and sealer filled area at all the evaluated levels in the presence or absence of isthmus

	Isthmus+			Isthmus−		
Group	*n*	GP (%)	Sealer (%)	*n*	GP (%)	Sealer (%)
Thermafil	21	80.1 (55.1–88.5)	19.1 (10.5–44.2)	24	85.2 (38.4–91.5)	14.7 (8.4–61.5)
System B	20	77.5 (41–93.5)	22.4 (6.5–58.1)	25	79.5 (51.7–94.2)	18.1 (5.7–41)
Lateral compaction	24	63.4 (44.5–78)	33.4 (20–55.4)	21	68.1 (43.1–94.1)	28.3 (5.8–56.8)
Single cone	23	55.4 (27.9–77.3)	41.4 (13.6–67.8)	22	68.9 (20.7–93.7)	28.6 (0–75.8)

Values represent median and range.

The analysis of all the sections studied revealed that a higher percentage of gutta-percha and less sealer and voids were found in root canals filled with Thermafil and System B techniques. Other significant differences are shown in Tables 2–5. The presence/absence of voids is shown in Tables 2–5. Overall, the single-cone and lateral compaction techniques had a higher incidence of voids ($P < 0.05$) (See Tables 3–5).

Isthmuses, had a negative affect the gutta-percha filled area only in the Thermafil technique ($P < 0.05$). (See Table 6). No relationship was found between the presence of isthmuses and the sealer distribution in all the evaluated techniques. The presence of isthmuses increased the presence of voids only in the lateral compaction group ($P < 0.05$).

Figures 1–3 show representative sections of the gutta-percha filled area, distribution of sealer and presence of voids in each of the groups. Figure 4 shows the number of sections with voids in presence or absence of isthmuses.

Discussion

A high incidence of isthmuses in mandibular molars between the 2 and 6 mm levels has been reported (Hsu & Kim 1997, Teixeira *et al.* 2003, Gu *et al.* 2009). This provided the rationale for the selection of these sections for the present study. Paque *et al.* (2009) reported that a considerable area of the root canal was not accessible to instrumentation, making it difficult to control several variables such as the length and the width of the isthmuses (Ordinola-Zapata *et al.* 2009b). Despite the inherent variability of such anatomy this study revealed differences in the quality of root fillings especially at the 4 and 6 mm levels, accepting partially the tested hypotheses.

The single-cone technique did not use compaction forces. The technique has been reported to fill the last 2 mm and to prevent the leakage as effectively as vertical and lateral compaction techniques (ElAyouti *et al.* 2009, Hammad *et al.* 2009, Ozawa *et al.* 2009). However, the single-cone technique may result in voids in irregular-shaped canal (Weis *et al.* 2004, Bergmans *et al.* 2005). Monticelli *et al.* (2007) reported that the leakage of two single-cone systems (GuttaFlow and Activgp) was greater than the System B technique at the coronal levels. These findings could be explained by the results of this study because at 4 and 6 mm levels, the thermoplasticized techniques had a higher percentage of gutta-percha and less sealer. Interestingly, the lateral compaction technique had a similar incidence of voids in comparison with the System B technique in the absence of isthmuses (Keçeci *et al.* 2005). In addition, the leakage of bacteria has been reported to be similar between the lateral and vertical compaction techniques (Brosco *et al.* 2010). However, in the presence of fins, the lateral compaction technique is less effective (Wu & Wesselink 2001).

In this study, the area of the carrier in the Thermafil specimens was included in the filled area in concordance with previous studies (De-Deus *et al.* 2006). The carrier can facilitate the movement of the filling material through the internal canal anatomy. Despite the good performance of the Thermafil system found in this and other studies (Gençoglu *et al.* 2002, Mirfendereski *et al.* 2009), a disadvantage of this technique is the higher risk of extrusion especially if the foramen is patent (Gutmann *et al.* 1993, Kytridou *et al.* 1999).

Confocal laser scanning microscopy is a versatile tool to study the cement/dentine interface and vitality of bacteria (Zapata *et al.* 2008, Bitter *et al.* 2009). These features can allow the patterns of bacterial colonization to be described in samples with leakage (Matharu *et al.* 2001). However, CLSM does not give volume information as does micro-CT data and can be considered as a destructive technique. Furthermore, future studies using micro-CT are necessary to elucidate the impact of each filling technique to fill complex root canal anatomy.

Conclusion

Gutta-percha, sealer filled area and voids were dependent on the canal-filling technique. The presence of isthmuses may influence the quality of root filling.

Acknowledgements

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