Introduction

Obturation of the root canal system is one of the important steps in root canal treatment. Obturation is considered as a function in which portals of entry between the canal and the periodontium are eliminated (1). In general, obturation involves a combination of core material, such as gutta-percha (GP) and a sealer (2). A good root canal obturating material should be well adapted to the canal walls and its irregularities. Thus, the entire length of the canal is densely compacted with a homogeneous mass of core filling material. Consequently, the quantity of core material should be maximized while the quantity of sealer should be minimized (3, 4). GP has been accepted as the gold standard root filling material (5), and the material against which most others are compared (6-8). Although GP and root canal sealers are used to obturate the root canals, they are incapable of accomplishing a good seal along the dentinal walls of the root canal (9). Because the adhesive potential of GP with canal sealers has been shown to be unsatisfactory, resin-coated GP points (EndoREZ® Points [ER Points]) have been introduced (10). ER Points facilitate a chemical bond with any resin-based sealer, thus creating a monoblock (11, 12). The term monoblock refers to the production of a single unit; however, recently it has been used for the introduction of adhesive root canal obturation materials (13).

The cold lateral compaction (CLC) of GP is considered as one of the most widely accepted canal obturation techniques and is taught in many dental schools (14). This is because of its advantages of controlled placement of GP in the root canal and low cost (15). With this technique, specially designed spreaders are placed as far apically as possible, and the master core filling is laterally compacted against the canal walls. Then, additional accessory points are inserted and compacted laterally around the master cone (16). The disadvantages of this technique include an increased risk of dentinal damage and vertical root fracture. Additionally, nonfilled spreader tracks are recurrently present in the filling which decreases the obturation quality (17). In contrast, the thermoplasticized GP technique can easily move GP into the canal irregularities, thus replicating the particulars of the root canal system (18).

Warm lateral compaction (WLC) of GP is a modification of CLC, which, at the same time, thermoplasticizes the entire GP obturation mass (19). In this technique, a heated spreader is used
to soften the GP inside the canal, and then a cold spreader is inserted to create sufficient space for accessory points (16, 20). To allow better adaptation of the GP points to the canal walls during the thermoplasticized GP technique, GP points with different tapers, 0.04-0.08, were introduced, which correspond to the taper of the rotary nickel-titanium (NiTi) instruments. Reports in the literature, however, suggest there is no advantage of 0.06 taper GP points over the 0.02 taper (21). Therefore, single cone (SC) obturation of root canals, a noncompaction technique, has recently been revitalized as a result of the introduction of a greater taper master core point (22). The SC technique may, moreover, produce an adequate root canal obturation without the use of more complicated and time-consuming techniques, such as lateral compaction or warm vertical compaction (23). Nevertheless, this technique relies on the original canal tapered circular preparation. Therefore, only small diameter and minimally curved roots are suitable for this technique (24).

There are many obturation materials and techniques that could be used to obturate the root canal space; however, studies that have investigated the root canal obturation quality using resin-coated GP points are sparse. Therefore, the aim of this study was to evaluate and compare the obturation quality of different obturation materials – GP points/AH Plus sealer and resin-coated GP/EndoREZ® sealer – using different obturation techniques (CLC, WLC and SC).

Materials and methods

Tooth collection, storage and selection

Two hundred extracted single-rooted mandibular premolar teeth were collected regardless of age and race. The teeth were stored in 0.5% chloramine-T trihydrate solution for 1 week. Ultrasonic scaler (Dentsply® Cavitron® Bobcat® Pro, USA) was used to remove both calculus deposits and residual periodontal tissues. Throughout this study, the teeth were kept hydrated in distilled water to maintain dentine permeability. The storage solution was changed regularly every 1 week, and the teeth were stored at 4°C.

A total of 90 of the 200 teeth had a single root canal, which was relatively straight, with a well-developed root and completely formed canal with patent foramen and teeth, with a canal diameter smaller or equal to a size 15 K-File (Colorinox; Dentsply Maillefer) at 4.5 mm from the radiographic apex, and these were used for the purposes of this study. In addition, an attempt was made to standardize the size and shape of the selected teeth (diameters at cervix were 5.0-5.5 mm mesiodistally and 7.5-8.0 mm buccolingually).

Canal preparation

The teeth were decoronated with a sectioning machine (Metkon® Micracut® 125 Low Speed Precision Cutter) at the level of 16 mm from the apex perpendicular to the long axis of the root canal, to relatively standardize the length for all specimens. The working length was determined by insertion of size 15 K-Files (Colorinox; Dentsply Maillefer) into the root canal until it was visible in the apical foramen, and then the working length of each canal was calculated to 1.0 mm short of that position. All root canals were prepared with the size 15 K-Files (Colorinox; Dentsply Maillefer) and Mtwo® NiTi rotary instrument (VDW, München, Germany).

Initially, the size 15 K-File (Colorinox; Dentsply Maillefer) was introduced into each root canal to produce a glide path, and then to complete the root canal preparation, the Mtwo® NiTi rotary instruments were used according to the manufacturer’s instructions, starting with size 15/0.05 to size 35/0.04, which was used as the master apical file (MAF). All rotary root canal instruments were used to the full working length of the canals, employing a cyclical in-out brushing motion. After each instrument, the canal was irrigated with 2.0 mL of 5.25% sodium hypochlorite (NaOCl) delivered using Ultradent® 5-mL syringe (Ultradent Products Inc., USA) with a 27-gauge needle (Ultradent). The apical patency was established throughout the preparation by passing a size 10K-File 1.0 mm beyond the apical foramen. Once root canal preparation was completed, each canal was then irrigated in the following sequence: 3.0 mL 5.25% NaOCl, 3.0 mL 18% ethylenediaminetetraacetic acid (EDTA) to remove the smear layer and finally 3.0 mL distilled water to ensure complete removal of the irrigation solutions from the root canal. Each irrigation solution was used for 1 minute.

Each specimen was then dried with a paper point (VDW, München, Germany) prior to the application of the obturation materials.

Canal obturation

A total of 90 mandibular premolar teeth were randomly divided into 2 main groups (2 x 45 canals): the GP group and the ER group. A total of 45 canals in each group was randomly divided into 3 subgroups (n = 15) according to different obturation techniques (CLC, WLC and SC).

CLC technique

CLC of GP

An ISO-standardized GP point size 35/0.02 (VDW, München, Germany) which fitted to the working length was chosen as the master cone. AH Plus sealer was placed into the canal using a paper point. The master cone was then placed to working length. A size 25 finger spreader (VDW, München, Germany) was advanced to within 1 mm of the working length, rotated and removed. Then, a GP accessory point size 25/0.02 (VDW, München, Germany) was placed into the prepared space. This was repeated until the spreader could not be inserted 2-3 mm into the canal. The excesses of the GP points were removed with a heat plugger standard BeeFill® 2in1 device (VDW, München, Germany). Following this, the GP in the coronal portion was vertically compacted using a root canal plugger, size 4.

CLC of ER

An ISO-standardized ER master cone size 35/0.02 (Ultra- dent) was chosen as a master cone. The ER sealer (Ultradent) was applied in the canal according to the manufacturer’s instructions, by inserting the delivery NaviTip (Ultradent) into the root canal to within 2-4 mm short of the apex. The tip was withdrawn slowly while expressing ER sealer coronally to the
A paper point, size 35, was then inserted to the working length and smeared onto the canal walls to remove excess sealer from the canal. Then the paper point was removed. The same steps were followed as described in the section “CLC of GP” to obturate the canals, except that the ER accessory point size 25/0.02 (Ultradent) was used instead of a GP point.

**WLC technique**

**WLC of GP**

An ISO-standardized GP point size 35/0.02 (VDW, München, Germany) which fitted to the working length was chosen as the master cone. AH Plus sealer was placed into the canal using a paper point. The master cone was then placed to the working length. A heat plugger standard BeeFill® 2in1 device was then introduced 2.0 mm short of the working length at 100°C (the lowest power setting). Next, the cold spreader was inserted 1 mm short of the working length, rotated and removed. Then, the first GP accessory point size 25/0.02 was inserted into the prepared space. This was repeated until the cold spreader could not be inserted 2-3 mm into the canal. The excess of the GP points was removed with a heat plugger standard BeeFill® 2in1 device. Next, the GP in the coronal portion was vertically compacted using a root canal plugger, size 4.

**WLC of ER**

An ISO-standardized ER point size 35/0.02 (Ultradent) which fitted to the working length was chosen as a master cone. The ER sealer (Ultradent) was then applied in the canal according to the manufacturer's instructions as described in the section “CLC of ER.” The master cone was inserted to the working length. A heat plugger standard BeeFill® 2in1 device was then introduced 2.0 mm short of the working length at 100°C. Next, the cold spreader was inserted 1 mm short of the working length, rotated and removed. The first ER accessory point size 25/0.02 was inserted into the prepared space. This was repeated until the cold spreader could not be inserted 2-3 mm into the canal. The same steps were followed as described in the section “WLC of GP.”

**SC technique**

**SC of GP**

AH Plus sealer was placed into the canal using a paper point. A standardized GP master cone size 35/0.04 (VDW, München, Germany) was placed to the working length, and GP accessory points size 25/0.02 were inserted passively into the canal. The excess of the GP points was removed with a heat plugger standard BeeFill® 2in1 device (VDW, München, Germany). Next, the GP in the coronal portion was vertically compacted using a root canal plugger, size 4.

**SC of ER**

A skinny syringe with a NaviTip was inserted 2-4 mm short of the apex, and ER sealer was introduced slowly while withdrawing the NaviTip from the canal space. A paper point was inserted into the canal to remove excess sealer. An ER master cone size 35/0.04 was placed to the working length, and ER accessory points 25/0.02 were placed passively in the root canal. The excess of the ER Points was removed with a heat plugger standard BeeFill® 2in1 device. Next, the ER Points in the coronal portion were vertically compacted using a root canal plugger, size 4.

In each GP and ER group, following the obturation technique, the access cavities of the specimens were restored with IRM (Dentsply Caulk, Milford, USA). Additionally, in the ER group, prior to placement of IRM, the coronal surface was light cured for 40 seconds to produce an immediate coronal seal, as recommended by the manufacturer.

All specimens were then kept in an incubator (Memmert, Germany) at 37°C in 100% humidity for 1 week, to allow complete setting of the sealer.

**Sectioning of specimens**

First, each specimen was fixed in a plastic cuvette using baseplate wax, and then embedded in epoxy resin. The epoxy resin was allowed to set for 24 hours. Next, the specimens were ground from the root tip with a grinding machine (METASERV® 2000 GRINDER POLISHER) until obturation material was visible.

All specimens in each subgroup were then sectioned horizontally perpendicular to the long axis with a sectioning machine (Metkon® Micracut® 125 Low Speed Precision Cutter). Each section was made using a diamond rotary blade with copious coolant irrigation to minimize smearing of the obturation material (GP or ER) at 4 levels: 1 mm (L1), 3 mm (L3), 6 mm (L6) and 9 mm (L9); as illustrated in Figure 1.

**Assessment of percentage of core filling material**

All sections were then viewed under a stereomicroscope (Olympus szx7; Olympus Corp., Tokyo, Japan) at ×40 magnification, and microscopic images were obtained.

The area occupied by core filling materials (GP or ER) was determined using Cell^D software (Olympus Soft Imaging Solutions GmbH, Münster, Germany). Next the percentage of core filling material in the canal filled area was calculated, as illustrated in Figure 2.

**Results**

Data were entered and analyzed using SPSS 12 for Windows (SPSS Inc., Chicago, IL, USA). The assumption of the outcome not being normally distributed and equality of variances were checked.

The differences between groups in the measurements of the core filling material in the canal filled area were compared using a nonparametric test (Mann-Whitney test). The significance level in this study was set at a p value <0.05.

**Percentage of core filling material (GP and ER) with CLC technique**

Table I shows that the percentage of core filling material was higher for the ER group at all levels than the GP group.
The highest percentage (median 100%) of core filling material in the ER group was at L3, and the lowest percentages (median 94%) were at L1 and L9. In the GP group, the highest percentages (median 93%) were observed at L3 and L6, and the lowest percentage (median 83%) was at L1. However, the ER group showed significantly higher percentages at L1 and L3 than the GP group (p = 0.005 and p = 0.023, respectively).

### Percentage of core filling material (GP and ER) with WLC technique

Table II shows that the percentages of core filling material were higher for the ER group at all levels than the GP group. The highest percentage (median 100%) was at L6, and the lowest percentage (median 88%) was at L1. However, the ER group showed significantly higher percentages at the L1, L3 and L9 levels than the GP group (p = 0.029, p = 0.006 and p = 0.007, respectively).

### Table II - Comparison of percentage of core filling material between GP and ER groups, using WLC

<table>
<thead>
<tr>
<th>Level</th>
<th>GP median, % (IQR)</th>
<th>ER median, % (IQR)</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>88 (18)</td>
<td>100 (9)</td>
<td>0.029</td>
</tr>
<tr>
<td>L3</td>
<td>92 (6)</td>
<td>100 (0)</td>
<td>0.006</td>
</tr>
<tr>
<td>L6</td>
<td>100 (3)</td>
<td>100 (0)</td>
<td>0.055</td>
</tr>
<tr>
<td>L9</td>
<td>97 (4)</td>
<td>100 (2)</td>
<td>0.007</td>
</tr>
</tbody>
</table>

ER = resin-coated GP; GP = gutta-percha; IQR = interquartile range; WLC = warm lateral compaction.

* Mann-Whitney test.

### Discussion

Lower premolar teeth were used in this study as samples, because they are known to have variations in root canal morphology, and some have an oval canal shape (25). Ingle et al described the shape of these canals in each third, as ovoid at the cervical third, round or ovoid at the middle third and round at the apical third. The preparation and
Table III - Comparison of percentage of core filling material between GP and ER groups, using SC

<table>
<thead>
<tr>
<th>Level</th>
<th>GP median, % (IQR)</th>
<th>ER median, % (IQR)</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>57 (22)</td>
<td>74 (17)</td>
<td>0.001</td>
</tr>
<tr>
<td>L3</td>
<td>66.23 (14)</td>
<td>90 (6)</td>
<td>0.000</td>
</tr>
<tr>
<td>L6</td>
<td>78 (14)</td>
<td>91 (8)</td>
<td>0.000</td>
</tr>
<tr>
<td>L9</td>
<td>82 (6)</td>
<td>94 (3)</td>
<td>0.000</td>
</tr>
</tbody>
</table>

ER = resin-coated GP; GP = gutta-percha; IQR = interquartile range; SC = single cone.
* Mann-Whitney test.

obturation of these canals have been considered to pose a challenge (25).

For many years, dye leakage studies have been the most commonly used method to evaluate the quality of root canal fillings. However, the reliability of those results has been questioned (26). This is due to the fact that the dye penetration may be hindered by entrapped air and may not be visible because the dye can lose its color when in contact with some root filling materials (24, 27). In general, good obturation should consist of a large amount of core material and minimal amount of sealer (28). This is because the sealer will be dissolved with time, thus creating spaces, which can act as a venue for a potential leakage area (25). Consequently, the percentage of GP-filled canal area has been used as a measure of obturation quality (29). A high percentage of core filling material with a low percentage of sealer plus voids indicates good obturation quality (27). Therefore, a cross-sectioning method was used in this study to evaluate the quality of 2 different materials (GP and ER) for each obturation technique.

The aim of root canal obturation is to provide a complete filling of the canal in all dimensions (3). A variety of materials and techniques have been developed to improve the sealing quality and reinforcing effect of root canal obturation (30). With the CLC technique, it has been shown that the apical seal is best produced when the spreader can be placed close to the working length (31). The spreader’s shape and its depth of penetration are considered to be important factors in producing a more homogenous root canal filling (32). In the current study, however, with the CLC technique, the percentage of ER core filling material was significantly higher than the percentage of GP core filling material, at L1 and L3 (p < 0.05). This might be due to the fact that with this technique, it was apparent that the depth of spreader penetration in the ER group was better than that in the GP group. This result is in agreement with a study performed by Nielsen and Baumgartner (33), who evaluated spreader penetration with Resilon® (a resin-based material) and GP using CLC. They found that spreader penetration was better with Resilon® than with GP. Improved penetration of a spreader may allow better placement of accessory points into the canals even to the apical third of the canal area, as observed in the ER group in this present study. However, there has not been an earlier study to investigate spreader penetration using the ER Points, thus no direct comparison can be made.

With the WLC technique, the percentage of core filling material in the ER group at the L1, L3 and L9 levels was higher than that in the GP group, with a significant difference for L1, L3 and L9 (p < 0.05). This might be associated with better plasticity and flow rate of the softened core filling material of the ER group compared with that of the GP group. This result was in agreement with that in a study performed by Epley et al (3), who evaluated obturation of lateral canals and found that the penetration of filling material was a function of the viscoelastic properties of the filling material. Moreover, Gurgel-Filho et al (34), who assessed the ability of different GP brands to fill simulated lateral canals, suggested that the brand of GP point had an influence on the length of filling within lateral canals. The flow rate capacity was affected directly by the variation in the amounts of zinc oxide and GP in the products. Higher amounts of GP in the composition of some commercial brands demonstrated a better ability to fill simulated accessory canals, wide canals and other anatomical irregularities (35). GP is a natural polymer that undergoes an industrial process prior to its use in the patient. This may influence its thermoplastics behavior (3). However, one should take into consideration the fact that the thermal properties of the ER Points have yet to be determined.

The SC technique was included in the present study based on the information mentioned by the manufacturer of ER to the effect that SC is the preferred technique. They mentioned that in large canals, additional ER point size 25/0.02 may be inserted as a “harpoon.” No “condensation” is necessary. With the SC technique, the ER group showed a higher percentage of core filling material than the GP group, with a statistically significant difference at all levels (p < 0.05). This might be due to the monoblock formation in the ER group. The monoblock concept refers to “the creation of a solid, bonded, continuous material from one dentine wall of the canal to the other” (36). Another research finding showed that a monoblock in ER obturation materials is created by deep penetration of the sealer into dentinal tubules and a chemical bond between ER sealer and ER Points (37).

Conclusions

Under the experimental conditions of the present study, the ER group was superior to the GP group in maximizing the percentage of core filling material occupying the canal area. Based on the different obturation techniques, the following conclusions can be reached:

1. CLC technique: the ER group was better than the GP group for maximizing the amount of filling core material at all levels, with a statistically significant difference at the 1- and 3-mm levels.
2. WLC technique: the ER group was better than the GP group for maximizing the amount of core filling material at L1, L3 and L9, with a statistically significant difference at the 1-, 3- and 9-mm levels.
3. SC technique: the ER group was better than the GP group for maximizing the amount of core filling material, with a statistically significant difference at all levels.
Obturation quality of gutta-percha and resin-coated gutta-percha

In conclusion, we can obviously note that with the SC technique, the amount of core filling material was higher than in the GP group. Therefore, if dental practitioners want to use a simple and fastest obturation technique (i.e., SC), they can select resin-coated GP/EndoREZ® sealer to obturate the root canal space. However, in this study, the SC technique was performed with a gentle “harpooning” motion using a greater tapered point with passive insertion of additional accessory points.

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Disclosures

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