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Original

Qualitative evaluation of two endodontic obturation techniques: tapered single-cone method *versus* warm vertical condensation and injection system An *in vitro* study

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Abstract: Forty two single-rooted teeth, prepared with the Mtwo system, were divided into three groups based on the filling method: control, "Single-cone" (*n* = 20) (Mtwo gutta-percha single-cone tapered according to the diameter, length and conicity of the preparation) and "Combined system" (*n* = 20) (BeeFill 2in1). The parameters studied were apical leakage, gutta-percha adjustment, number of voids, presence/absence of sealer, root canal morphology, residual fragments, and filling of lateral/accessory canals. A dye penetration test was carried out (methylene blue). The teeth were embedded in resin, cut transversally and observed. The data were analyzed with non-parametric Mann-Whitney and Spearman tests. Comparative tests between the two groups showed that the "Combined system" was superior in terms of apical leakage ($P < 0.01$), gutta-percha adjustment ($P < 0.05$) and filling of lateral/accessory canals ($P < 0.05$). There were statistically significant correlations between master cone adjustment and root canal morphology ($P < 0.01$) in the "Single-cone" group. In the "Combined system" group, a relation was observed between the voids and root canal morphology ($P < 0.05$) and between voids and residual fragments ($P < 0.05$). The quality of obturation with warm gutta-percha was better than that of the tapered single-cone technique. Root canal morphology influences gutta-percha adjustment. Residual fragments on the root canal reduce sealing ability. (J Oral Sci 54, 99-104, 2012)

Keywords: single-cone; combined systems; root-end filling material; sealing ability.

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Introduction

The success of endodontic treatment depends on the quality of the root canal preparation (cleaning and shaping). Its lifespan is guaranteed by a hermetic root canal filling and coronal restoration. The extremely complex apical zone is the path of entry for bacteria and their toxins. In order to seal the whole root canal system, it is indispensable that the filling should be three-dimensional and hermetic; particularly in the last few millimeters of the apical area.

The obturation technique using a single-cone with low conicity embedded in root canal sealer exhibits low sealing ability due to excess of the sealer (1).

The root canal preparations with NiTi rotary systems are more conical than manual preparations. Tapered

single cones were introduced in the market in order to improve the gutta-percha/root canal sealer balance (2). If the diameter and conicity correspond exactly with the final shaping instrument, the quality of obturation would be superior to that of the classic single-cone technique.

Warm gutta-percha filling is the standard material used, but it requires longer time and is difficult to apply (3). Many practitioners have therefore turned to combined systems, particularly those which associate warm vertical condensation to provide an apical seal, and injection of warm gutta-percha in order to fill the coronal two thirds of the root canal (BeeFill 2in1, Calamus, Elements, System B/Obtura II). This method allows us to obtain the advantages of a continuous filling, while limiting its drawbacks (4).

The aim of this study was to evaluate the overall quality of a filling technique by tapered single cone *versus* the combined system.

We hypothesised that the use of tapered cones with diameter and conicity corresponding to the last-used shaping instrument would allow a quality of obturation approaching that of warm condensed gutta-percha.

This study compared the tapered single-cone Mtwo (VDW, Munich, Germany) technique and the BeeFill 2in1 (VDW, Munich, Germany) combined system; in terms of apical microleakage, master-cone adjustment, the presence or absence of root canal sealer, the number of voids and the filling of lateral or accessory canals; and finally, evaluated the maintenance of the root canal morphology and the preparation quality.

Materials and Methods

Specimen preparation

A total of 42 permanent maxillary and mandibular single-rooted teeth (incisors, canines and premolars) were selected and preserved in an aqueous solution of 2.5% sodium hypochlorite before and after preparation. These teeth were mature and non-carious, and had been freshly extracted for prosthetic, periodontal or orthodontic reasons.

The experiments were carried out by a single general dentist. Two preoperative radiographs were taken in buccolingual and mesiodistal direction using argentic and digital techniques. The access cavities were prepared with LN: (Dentsply-Maillefer, Montigny-le-Bretonneux, France), Zekrya-endo (Dentsply-Maillefer) and Gates (Dentsply-Maillefer) drills. The root canal was prepared with manual files (MMC, MME: MicroMega, Besançon, France) at 8, 10 and 15/100. The working lengths were determined visually 0.5 mm short of the apical foramen with the 15/100 file.

All the samples were prepared with the Mtwo (VDW, Munich, Germany) files #10.04, #15.05, #20.06, #25.06, mounted on the VDW Gold (VDW) motor (350 rpm) following the "unique length" technique. The standard irrigation protocol using EDTA gel (FileCare, VDW) and sodium hypochlorite (NaOCl) at 2.5% through the opening of the pulp chamber and between uses of instruments was followed. The final irrigation was performed with an aqueous EDTA solution at 17% for 3 min, followed by rinsing with NaOCl.

Formation of experimental groups

The samples were randomly divided into two experimental groups ($n = 20$/group) and a control group ($n = 2$), based on the obturation technique used.

"Single-cone" (Mtwo tapered single-cone): A single cone of gutta-percha tapered with diameter and conicity corresponding to the final shaping instrument (#25.06), was tried in the root canal after visual and tug-back control. The canal was dried, the sealer inserted (Endobtur, Septodont, Saint Maur des Fossés, France) and the single cone inserted to the working-length. The excess of gutta-percha was removed with a heated instrument.

"Combined system" (BeeFill 2in1): The apical third was filled by warm vertical condensation using heat-carrier (Downpack) and hand pluggers chosen according to the root canals, and the same sealer as in the "Single-cone" group. The coronal two-thirds were filled with warm gutta-percha injected by the backfill handpiece following the manufacturer's instructions.

"Control": This group was composed of a non-filled and totally varnished tooth, and a non-filled and non-varnished tooth. This group was meant to test the insulation capacity of the varnish and penetration capacity of the dye.

After filling, the samples were radiographed using digital and argentic techniques (buccolingual incidence), and reconditioned in a NaOCl solution at 2.5%.

Evaluation of parameters

The seven variables were defined as follows:

Microleakage: The dye penetration of methylene blue at 2% was chosen in order to evaluate apical microleakage. The samples were dried and nail varnish (Classic Cement Spacer, KerrLab, West Collins, CO, USA) was applied from the cementoenamel junction up to 2 mm from the apex. Dye penetration was only possible through the apical foramen. Each tooth was placed in a tube with 100 µL of methylene blue for 24h, with the apex completely immersed in the dye. The tubes were covered with Parafilm (Pechiney plastic packaging, Chicago, IL,

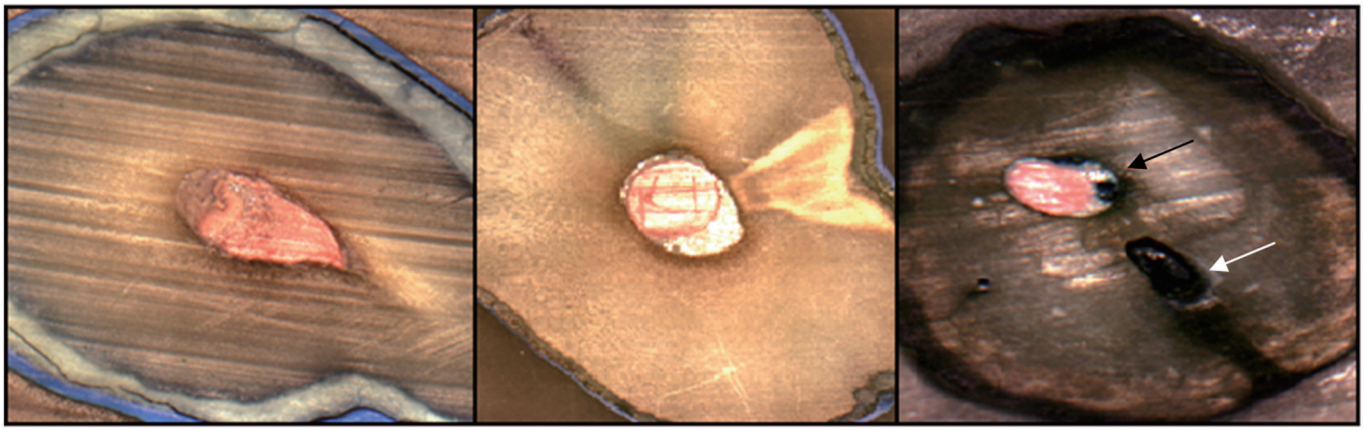

Fig. 1 From left to right: Hermetic specimen filled with BeeFill 2in1 (×20); Hermetic specimen filled with Mtwo single-cone (×20); Non-hermetic specimen filled with Mtwo single-cone with oval root canal and non-obturated accessory root canal (×40).

USA) in order to avoid evaporation. The samples were rinsed with tap water, dried and embedded in resin blocks (Araldite 2020 , Huntsman, Basel, Switzerland) that were cut horizontally with a low-speed saw (Isomet, Buelhler Ltd, Dusseldorf, Germany) under water spray. The slices were cut at 1-mm intervals from the apex towards the cementoenamel junction, over a distance of 7 mm. The thickness of the slices was set at 0.5 mm, so that it was possible to read both sides. The specimens were observed with a binocular microscope at ×20 and ×40. The slices were oriented, marked and archived. Apical microleakage was evaluated by dye penetration in mm (Fig. 1).

Master cone adjustment: The root canal system should be completely obturated by a central mass of gutta-percha, from the root canal entrance to the working length. We measured the lack of obturation ability between the working length and the master cone in mm.

Sealer: The space between the gutta-percha cone and root canal walls must be filled with a small quantity of sealer, which prevents apical microleakage. We measured the presence of sealer between the working length and gutta-percha in mm.

Voids: The filling material, both the central mass of gutta-percha and the sealer around it, must be free from voids. We counted the voids in each sample.

Lateral or accessory canals: Lateral and accessory canals may open the way to bacterial infection; therefore, it is necessary to obturate them to the greatest possible extent. We determined the presence or absence of lateral or accessory canals, and whether they were filled with sealer or gutta-percha.

Residual fragments: If the root canal has not been correctly prepared, residual matter (dentin debris, bacteria, pulp parenchyma) may remain on the root canal walls. For each tooth, the number of sites with residual fragments was counted.

Root canal morphology: The quality of the obturation may be influenced by the morphology of the root canal (round or oval). For this reason, root canal morphology of the samples 7 mm from the apical region was evaluated after allotting a value of 0 for a circular canal and 1 for an oval canal for each slice. The sum of these values provided information about the approximate root canal morphology at the end of the preparation.

The statistical analysis comprised two parts: first, Mann-Whitney non-parametric tests were conducted in order to compare the variables in the two groups. Secondly, Spearman non-parametric tests were carried out so as to look for a relation between two variables within each group. A statistically significant difference or correlation was noted when $P < 0.05$.

Results

The negative control showed no dye penetration. This confirmed the insulating capacity of the varnish. The penetration capacity of the dye was demonstrated by the presence of dye on all slices of the positive control.

A homogeneity control test was performed for the variables working length, residual fragments, root canal morphology and lateral or accessory canals. The non-parametric tests of Wilcoxon did not show any significant difference ($P > 0.05$) between the two groups. We can therefore say that the variables were homogeneously distributed in this study.

First, the mean values ± standard deviation of the two groups were compared (Table 1). A significantly higher level of dye penetration ($P < 0.01$) was observed in the "Single-cone" group. Adjustment of gutta-percha ($P <$

Table 1 Evaluation of the variables in the "Single-cone" and "Combined system" groups. Results of the Mann-Whitney tests

Tested Variable	Single-cone group Mean ± standard deviation	Combined system group Mean ± standard deviation	*P* value
Microleakage (mm)	6.575 ± 2.2	4.425 ± 1.18	< 0.01
Master cone adjustment (mm)	1.15 ± 1	0.7 ± 0.66	< 0.05
Sealer (mm)	0.2 ± 0.41	0.1 ± 0.3	> 0.05
Voids (nb/tooth)	2.1 ± 1.55	1.4 ± 1.27	> 0.05
Non-filled lateral canals (nb/tooth)	0.35 ± 0.67	0 ± 0	< 0.05
Filled lateral canals (nb/tooth)	0.25 ± 0.44	0.75 ± 0.91	> 0.05
Residual fragments (nb/tooth)	0.95 ± 0.99	0.5 ± 1	> 0.05
Root canal morphology (tendency)	2.75 ± 2.93	3.45 ± 3.2	> 0.05
Lateral canals (nb/tooth)	0.6 ± 0.82	0.7 ± 0.86	> 0.05

0.05) and the number of filled lateral or accessory canals ($P < 0.05$) were significantly higher in the "Combined system" group.

The second part of the statistical analysis dealt with the relations between different variables inside each group. In the "Single-cone" group, we observed statistically significant correlations between root canal morphology and gutta-percha adjustment ($P < 0.01$). The "Combined system" group displayed a significant correlation between the number of voids and root canal morphology ($P < 0.05$), and between the variables, residual fragments and number of voids ($P < 0.05$).

Discussion

The dye penetration test is easy to perform. The high penetrating and tinting ability of methylene blue in endodontic fillings makes it the most commonly used dye. Some authors prefer to combine this technique with the fluid filtration method (5,6), while others believe that the results of bacterial tests offer a better approximation of clinical reality (7). However, this apical microleakage evaluation model has recently been challenged (8).

The dye penetration method permits comparison of the apical leakage in two groups under identical rigorous experimental conditions, and provides a realistic imitation of clinical conditions.

With regard to microleakage, the samples filled by the combined system showed a better apical sealing ability (Table 1). These results were in agreement with those of most previous studies (5,9-11).

Nevertheless, only the work of Yilmaz et al. demonstrated different results (12). They revealed that the teeth filled using the combined system had a higher leakage than the single-cone group. However, there were only 10 samples in each group in this study, there was no control group, and the mean and standard deviation were only presented on a box-plot. This made any power/sample size calculation impossible. These results were surprising and questionable, but the study has the merit of putting the question at the heart of the debate.

As far as master cone adjustment is concerned, a better apical adjustment of gutta-percha was perceived with the combined-system filling technique (Table 1). The lack of calibration of the manufactured cone was observed in the "Single-cone" group when it was applied by warm vertical condensation while achieving an apical seal in the "Combined system" group. These results were confirmed in the literature (13-15). Moreover, the present study showed a greater number of filled lateral or accessory root canals in the "Combined system" group (Table 1). These results are also consistent with previous findings (16,17). Heating and plugging the gutta-percha allows realization of a mould of the canal that increases apical adjustment and propels the sealer cement into the anatomical variations.

A statistically significant correlation was found between root canal morphology and the master cone adjustment variables in the "Single-cone" group. When the morphology was oval, we observed better gutta-percha adjustment. This could be explained by the smaller amount of friction between the master-cone and the root canal walls in an oval canal compared with a circular canal. This correlation was not found in the "Combined system" group. This was to be expected, because if the gutta-percha is heated and condensed, the root canal morphology no longer matters. It will be necessary to find a consensus on the definition of the notion 'oval root canal'. Indeed, the root canal morphology may change depending on the distance from the apex. We tried to compensate for this bias by adding up the slices where the root canals were oval for each tooth.

This study demonstrated a statistically significant

correlation between the number of voids and root canal morphology in the "Combined system" group (Table 2). When the canal was oval, more voids were observed. This can be explained by the difficulty of obturating an entirely oval root canal by complex and insufficient gutta-percha compaction, especially in the coronal two thirds. This correlation was not found in the "Single-cone" group whereas the sealer mass was more important in the oval root canals and it has a great retraction coefficient susceptible to contain the voids (1).

A final significant correlation was observed between the number of voids and the presence of residual fragments on the root canal walls in the "Combined system" group. Insufficient cleaning or shaping can leave residual fragments, such as dentin debris, bacteria, or pulp parenchyma. The joint between the filling materials is thus imperfect, making dye penetration possible. The fragments present on the root canal walls reduce the precision of the joint between gutta-percha, sealer and root canal walls, and alter the sealing ability of the endodontic treatment.

In conclusion, the analysis of the different parameters allows us to say that:

- Heating and plugging the gutta-percha significantly increases apical sealing ability, adaptation to the root canal walls, apical adjustment of gutta-percha and the propulsion of filling materials into lateral or accessory canals.
- Cleaning and shaping are essential to prevent microleakage and increase the lifespan of the obturation.

More studies are required to confirm the relevance of the present results.

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