Original Article

Evaluation of Various Filling Techniques in Distal Canals of Mandibular Molars Instrumented with Different Single-File Nickel-Titanium Systems

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Abstract

Background and Aims: The aim of this study was to evaluate the quality of various filling techniques in distal canals of mandibular molars instrumented with different single-file nickel-titanium (NiTi) systems. **Materials and Methods:** A total of 150 distal roots of mandibular molar teeth were randomly assigned into three main groups and instrumented by using Reciproc (VDW, Munich, Germany), WaveOne (Dentsply Tulsa, Tulsa, OK, USA), or One Shape (MicroMega, Besancon, France) NiTi file systems. The roots were then treated using one of five filling techniques: (1) Matched-single-cone, (2) cold lateral compaction with matched gutta-percha (GP) cone, (3) Thermafil filling, (4) System B/Obtura II, and (5) lateral compaction with standardized GP cones. The roots were then sectioned at three levels (coronal, middle, and apical). Photographs were acquired under a stereomicroscope, and the percentage of GP-filled areas (PGFAs), percentage of sealer-filled areas (PSFAs), and voids were measured using the ImageJ software. Comparisons between groups were applied using Student's *t*-test or one-way ANOVA for normally distributed data. The Mann-Whitney U-test or Kruskal-Wallis test was used when variables were not normally distributed. **Results:** Canals filled with the System B/Obtura showed the highest PGFA and lowest PSFA, whereas those filled with matched-single-cone showed the highest PSFA and lowest PGFA ($P < 0.05$). The cold lateral compaction with matched GP cone group, lateral compaction group, and Thermafil filling group showed no statistically significant differences in PSFA and PGFA ($P > 0.05$). **Conclusions:** System B/Obtura technique appears to be the best technique to properly fill root canals, whereas the matched-single-cone technique in oval-shaped distal canals of mandibular molars was inadequate.

Keywords: *Reciprocating files, root canal fillings, rotary files,*

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Introduction

Instrumentation and filling techniques are both important parts of a successful root canal treatment.[1,2] For instrumentation, the newly manufactured nickel-titanium (NiTi) file systems are claimed to be able to prepare and clean root canals using only one file. Two of these single-file systems; Reciproc (VDW, Munich, Germany) and WaveOne (Dentsply Tulsa, Tulsa, OK, USA) are used in a reciprocating motion and another single-file system One Shape (Micro Mega, Besancon, France) is used in a traditional, continuous, and rotational motion.

There are several proposed techniques to achieve adequate three-dimensional filling of the well-instrumented root canals.[3] One of the best-known technique is lateral compaction of cold gutta-percha (GP) which is often used as a standard to compare new techniques.[4] However, this method is reported to have possible disadvantages such as inhomogeneity, an increased risk of canal fracture, and poor adaptation to the canal walls.[4] The other widely used technique is the warm vertical compaction of GP which is made by System B endodontic heat source unit (SybronEndo, Redmond, WA, USA) combined with a thermoplasticized GP injection system, Obtura II (Obtura Spartan, Fenton, USA). These systems were effective for downpack and backfill filling of the root canal system but require relatively long time, and application can be difficult especially in molar teeth.[5]

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Recently, corresponding GP cones that match the taper and diameter of the files have been manufactured. Filling with this system may be less complex and time-consuming because these instruments and cones attempt to prepare a root canal to a certain shape and then fill the canal using a single GP cone.[6] There are a few suggestions regarding the appropriate use of matching GP cones in a "single-cone technique" or in combination with accessory cones.[7] Because the volume of sealer required for the single-cone technique is much more than the volume necessary to complete a compaction technique.[8] Carrier-based obturators were manufactured for reduce the amount of sealer used during the filling. This filling technique provides to compact thermo plasticized GP and sealer both laterally and vertically more rapidly than other techniques.[4]

All filling methods aim the maximum volume of GP and a thin layer of sealer because the sealer may shrink during setting and dissolve over time, causing leakage.[9] It is well-known that the coronal and apical leakages have important effects on the long-term success of endodontic treatment.[10] The percentage of GP-filled areas (PGFAs) has been used as a measure of the quality of the root filling.[7] Therefore, the aim of this study was to compare different filling techniques in the distal canals of lower molars, instrumented by different single-file systems, and the canal area in terms of the percentage of GP, sealer, and voids. The hypothesis of this study was that there would be a difference between different obturation techniques for the percentage of GP and sealer.

Materials and Methods

A total of 150 extracted human mandibular molar teeth were selected for the study which had been stored in 10% formalin. The extracted teeth were obtained from patients affected by dental caries or severe periodontal disease. The study was conducted in full accordance with the World Medical Association Declaration of Helsinki. The research protocol and the informed consent form were approved by the Bioethics Committee of the University of Cukurova.

The crowns and distal roots were separated using a high-speed water-cooled diamond bur and 150 distal roots were assigned randomly into three groups of 50 teeth each and enlarged with Reciproc or Wave One or One shape file system. A size 10 H-file (Dentsply Maillefer, Ballaigues, Switzerland) was introduced into each of the canal until it appeared at the apical foramen, and the working length was established by subtracting 1 mm from this measurement.

Instrumentation was performed by a single operator (A.D.) in accordance with the manufacturers' recommendations. Moreover, all files were operated with a torque controlled motor (VDW Silver). Primary Wave One files (size 25, taper 0.08) and Reciproc R25 files (size 25, taper 0.08) were operated in a reciprocating motion using preset adjustments, while One Shape files (size 25, taper 0.06) were used with in and out movements without pressure at a 400 tr/min rotation speed and 2. N.cm torque. In total, 5 ml of 2.5% NaOCl was used for irrigation of the canals. Before filling, each canal was flushed with saline solution and then dried with paper points. Prepared roots for each rotary system (n = 50/group) were divided randomly into the five groups (n = 10/group) based on the filling technique used. A total 15 experimental groups were assessed, and the teeth were then filled, as follows. For all filling techniques, Endoplus (President Dental, Duisburg, Germany) sealer was used.

Matched-single-cone filling

The root canals were filled with a size 25# specific single GP cone according to the NiTi file. (size 25# 0.08 tapered single GP cone (VDW, Munich, Germany) for Reciproc instrumentation group, size 25# 0.08 tapered single GP cone (Dentsply Maillefer, Switzerland, Brazil) for WaveOne instrumentation group, and size 25# 0.06 tapered single GP cone (MicroMega, Besancon, France) for One Shape instrumentation group).

Cold lateral compaction with a matched gutta-percha cone

A size 25# specific single GP cone with sealer-coated 0.02/20 accessory cones were used for filling of root canals.

Thermafil filling

For Reciproc; size R25 Guttafusion obturators, for WaveOne; 25 thermafil plastic obturators, for One Shape; 25 Herofill obturators were used to obturate the root canals.

System B/Obtura II warm vertical compaction

The apical third of root canal was filled with System B/ Obtura II was used for the backfill filling of root canal.

Cold lateral compaction

Root canals were filled with cold lateral compaction with size 25# standardized GP cones and accessory GP cones.

All fillings were completed by the same endodontist (A.D.), who was proficient in all filling techniques used. The specimens were stored in an incubator for 2 weeks at 37°C and 100% humidity to allow the sealer to set completely.

Root sectioning and image capture and analysis

A low-speed diamond-coated saw was used to section the roots horizontally at coronal, middle, and apical level with continuous water irrigation to prevent overheating (EXAKT 300 CL, Exakt Apparatbau, Norderstad,

Germany). Sections were viewed at ×40 magnification using a stereomicroscope (Olympus SZ61, Olympus Corp., Tokyo, Japan) and digital images were captured with a digital camera (QImaging, BC, Canada) that attached to the stereomicroscope. On these digital images of each segment, the total area of each canal section and the areas of its contents (GP, sealer, voids) were measured in a metric system using the Image J (National Institutes of Health, Bethesda, MD, USA). The areas of GP, sealer, and voids were converted to percentages of the total area. The analysis of these cross-sections was performed by a second examiner who was blinded with respect to the experimental groups. For each section, measurements were repeated 3 times and the means were calculated. The accuracy rate of the examiners was 0.84 according to a correlation test.

Statistical analysis

For each continuous variable, normality was checked. Because the data were not distributed normally, an appropriate nonparametric test was used. Comparisons between groups were applied using Student's *t*-test or one-way ANOVA for normally distributed data. The Mann-Whitney U-test or Kruskal-Wallis test was used when variables were not normally distributed. A univariate general linear model was applied to evaluate the related factors. If there were significant differences among the groups, the analysis was continued with *post hoc* comparisons using Tamhane's, Dunnett's, or Mann-Whitney U-test. Bonferroni's correction was applied ($P < 0.05/n$; where n = a number of comparisons) when multiple comparisons were performed. Results are presented as means ± standard deviation. All reported P values are two-tailed. The SPSS statistical software (version 20.0; SPSS Inc., Chicago, IL, USA) was used for statistical analysis of the data.

Results

The distribution of the PGFAs, the percentage of sealer-filled areas (PSFAs), and voids levels regarding to the instrumentation techniques, filling techniques, and localization groups were shown in Table 1. There was no significant difference in voids levels among the instrumentation groups ($P = 0.333$), there were significant differences between the groups according to the PGFA and PSFA levels ($P < 0.001$ for all comparisons). Reciproc instrumentation group demonstrated the highest PGFA and lowest PSFA level compare to the Wave One and One Shape instrumentation group.

The distribution of the PGFA, PSFA, and voids levels regarding to the subgroups were shown in [Table 2]. Significant differences were found among the five obturation technique groups in the distribution of GP, sealer, and voids ($P = 0.0001$, $P = 0.0001$, and $P = 0.001$, respectively). Canals filled with the System B + Obtura technique showed the highest PGFA and lowest PSFA and canals those filled with the matched-single-cone technique showed the highest PSFA and lowest PGFA.

Regarding localization, the ratio of PGFA was lower at the apical localization than the middle or coronal localization ($P = 0.050$). There were no significant differences among the localization groups according to PSFA and voids levels ($P = 0.964$ and $P = 0.101$, respectively). The distribution of the PGFA, PSFA, and voids levels regarding to the subgroups were shown in Table 2. The System B + Obtura technique showed the highest PGFA and lowest PSFA and voids levels in all instrumentation techniques groups. Hence, univariate general linear model analyses revealed that there is no significant interaction between instrumentation techniques and localization groups. There is significant interaction between obturation and instrumentation techniques and localization groups. Representative cross-section images from each experimental group at the middle level are shown in Figure 1.

Table 1: The distribution of the PGFA, PSFA and voids levels regarding to the instrumentation techniques, obturation techniques and localization groups

Groups	Subgroups	Mean±SD (median)		
		PGFA	PSFA	Voids
Instrumentation techniques	Wave-one	68.5±22.8 (70.6)	30.3±22.4 (27.3)	1.2±3.3 (0.0)
	One-shape	68.0±23.0 (64.7)	30.4±22.5 (29.7)	1.6±4.3 (0.0)
	Resiproc	79.4±18.6 (82.7)	18.6±17.5 (15.4)	1.9±4.5 (0.0)
	P	0.0001	0.0001	0.333
Obturation techniques	Single cone	51.8±21.3 (45.3)	46.4±21.7 (52.4)	1.9±4.7 (0.0)
	Single cone + lateral	73.1±16.7 (73.6)	25.4±15.9 (25.3)	1.5±3.1 (0.0)
	Thermafil	71.5±17.2 (67.2)	25.9±17.0 (26.5)	2.6±5.7 (0.0)
	System B+ obtura	85.9±24.1 (99.5)	13.6±23.1 (0.0)	0.6±2.8 (0.0)
	Lateral con.	76.6±16.5 (78.4)	22.1±16.0 (21.1)	1.3±2.8 (0.0)
	P	0.0001	0.0001	0.001
Localization	Coronal	74.5±20.9 (76.7)	24.3±20.3 (22.1)	1.2±2.8 (0.0)
	Middle	73.3±20.4 (76.4)	25.1±19.8 (21.6)	1.6±4.0 (0.0)
	Apical	68.0±24.5 (68.4)	30.0±24.1 (28.1)	2.0±5.1 (0.0)
	P	0.050	0.964	0.101

PGFA=Percentage of gutta-percha filled areas, PSFA=Percentage of sealer filled areas

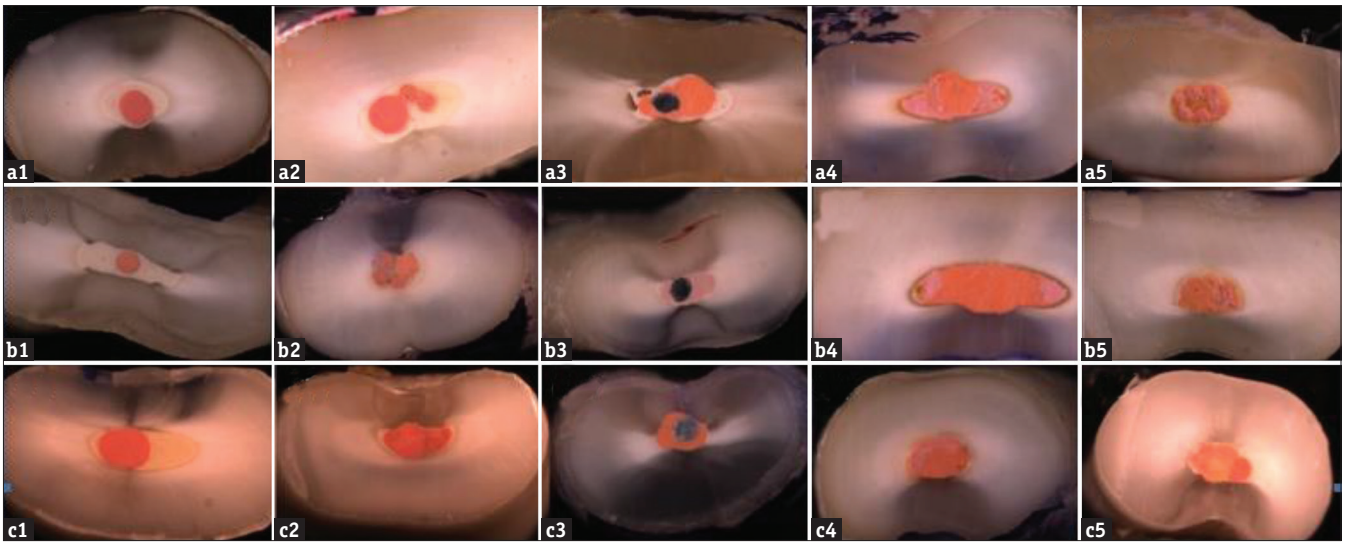

Figure 1: Cross-section of the different root canal filling techniques. (1) Matched-single-cone; (2) lateral compaction with matched gutta-percha cone; (3) Thermafil; (4) System B/Obtura II; and (5) lateral compaction with standardized gutta-percha cones which are instrumented with (a) WaveOne, (b) One Shape, (c) Reciproc file systems

Table 2: The distribution of the PGFA, PSFA and voids levels regarding to the subgroups

	PGFA Mean±SD			PSFA Mean±SD			VOIDS Mean±SD		
	Coronal	Middle	Apical	Coronal	Middle	Apical	Coronal	Middle	Apical
Wave one									
Single cone	42.9±12.9	39.4±10.0	42.3±10.4	57.1±12.9	60.5±9.9	56.7±10.3	0.0±0.0	0.1±0.5	1.0±2.5
Single cone + lateral	68.1±14.4	69.6±16.4	64.6±15.1	31.4±14.3	28.3±14.7	33.8±13.4	0.5±1.1	2.1±4.0	1.6±4.0
Thermafil	76.8±13.7	73.4±12.0	70.6±23.8	20.7±13.2	21.6±11.2	27.1±24.0	2.5±2.8	5.0±7.7	2.3±5.2
System B + obtura	95.5±8.5	95.1±6.0	68.7±34.1	4.5±8.5	4.9±6.0	29.7±32.9	0.0±0.1	0.0±0.0	1.6±4.7
Lateral con.	77.7±12.2	78.9±13.7	68.9±16.9	22.2±12.0	20.7±13.7	28.6±14.2	0.1±0.4	0.4±0.7	2.5±4.1
One shape									
Single cone	46.3±16.4	40.9±13.8	42.6±23.1	52.0±15.5	56.0±15.2	54.9±25.8	1.7±3.7	3.1±5.4	2.5±8.0
Single cone + lateral	68.5±15.7	67.3±11.5	58.5±11.2	29.5±14.7	31.1±10.8	39.7±11.0	1.9±3.0	1.7±3.6	1.7±3.2
Thermafil	65.7±16.7	66.4±15.9	81.2±19.6	33.2±16.0	33.2±15.8	14.2±16.1	1.1±3.8	0.5±1.6	4.5±8.6
System B + obtura	95.3±8.8	95.2±6.0	68.2±34.8	4.7±8.8	4.8±6.0	30.1±33.7	0.0±0.2	0.0±0.0	1.7±4.7
Lateral con.	75.7±24.5	76.7±12.4	64.0±19.3	23.5±23.4	22.7±12.1	33.8±20.7	0.8±1.8	0.7±2.3	2.1±4.6
Resiproc									
Single cone	67.2±19.8	65.9±16.5	82.5±16.7	28.4±18.0	29.3±15.1	17.5±16.7	4.5±5.7	4.8±7.0	0.0±0.0
Single cone + lateral	88.3±7.7	88.7±8.2	91.2±9.9	10.7±6.9	10.7±7.8	6.9±6.9	1.0±1.7	0.6±1.3	1.9±4.5
Thermafil	71.6±14.2	67.4±16.9	75.2±18.3	25.6±14.5	29.8±16.2	22.4±17.9	2.8±4.5	2.8±5.6	2.5±8.5
System B + obtura	95.3±8.8	95.0±6.6	64.4±34.8	4.7±8.8	5.0±6.6	33.7±33.5	0.0±0.1	0.0±0.0	1.9±5.0
Lateral con.	85.8±12.7	83.3±8.4	81.5±14.5	13.4±11.5	13.8±7.6	16.7±14.0	0.9±1.7	2.9±3.7	1.7±2.4

PGFA=Percentage of gutta-percha filled areas, PSFA=Percentage of sealer filled areas

Discussion

In this study, the Reciproc instrumentation group demonstrated higher PGFA and lower PSFA compared to the WaveOne and One Shape instrumentation groups in this study. Reciproc, WaveOne, and One Shape systems attempt to provide a single-file shaping technique without considering the length, diameter, or curvature of any given canal. In the current study, single-file systems with a tip diameter equivalent to a size of 25 file were selected for all instrumentation groups, even though Reciproc, WaveOne, and One Shape files have variable tapers (respectively, 0.08 taper, 0.08 taper, and 0.06 taper). The study outcome of the Reciproc group might be due to the cross-sectional design of the Reciproc file, which has a double cutting edge S-shaped geometry that provides high cutting efficacy.[11] Canals prepared with Reciproc file system might be filled and condensed better than those prepared with other file systems.

Moreover, when analyzing the localization, the ratio of PGFA was lower at the apical level than at the middle or

coronal level ($P < 0.05$) for all groups investigated. This is possibly due to the oval shape or complex anatomy of distal canals of mandibular molars stemming from irregular canal shape and inadequate biomechanical preparation, which might be negatively affecting the filling quality. The percentage of voids for all groups was very low in this study, but the Thermafil technique had statistically more voids than the System B + Obtura obturation technique due to the root canal anatomy. Filling with one carrier was not sufficient for oval-shaped canals, so irregular canals should be filled with two carriers to decrease the sealer and void percentage.

System B + Obtura filling technique demonstrated the highest PGFA and lowest PSFA since heating and plugging of the GP significantly increased the sealing of lateral and accessory canals.[12] Thus, the hypothesis of this study was accepted. However, this technique showed decreased PGFA values and increased PSFA values at the apical level. This may be arisen because the GP in the apical portion of the root canal had not been softened adequately by heat and thereby GP adaptation was not performed. In parallel with this result, Cathro and Love[5] reported that the System B/Obtura II technique resulted in PGFA values of 99.5%, 99.4%, 100%, and 100% at 2, 4, 6, and 8 mm from apex, respectively, in standard resin canals.

Matched-single-cone filling is another filling technique which has been developed to minimize sealer content through the use of GP cones that closely match the geometry of the NiTi instrumentation systems.[13] However, there is doubt regarding the manufacturers' claims for the supposed close matching of instruments and cone shapes because the files and cones often do not seem to match.[14] Some studies have evaluated the quality of these single-cone fillings in terms of sealing ability,[15,16] bond strength,[17] radiographic quality,[9] PGFA, and PSFA.[7] Schäfer *et al.*,[7] reported similar PGFAs and PSFAs in canals filled either with lateral compaction of matched GP cones, warm vertical compaction, or lateral compaction of standardized GP cones at all levels evaluated, although the single-cone obturation resulted in a significantly lower values for GP and higher for sealer-filled areas. Another study by Pommel and Camps,[18] showed that the matched-single-cone technique produced the greatest amount of apical leakage. These studies are inconsistent with the current study but contradictory to this study Gordon *et al.*,[19] showed no significantly difference between the single-cone and the lateral condensation. In addition, Tasdemir *et al.*,[20] suggested that the matched-single-cone technique with tapered GP cones may yield better filling than the lateral compaction technique, at a level 2 mm from the apex. Another *in vivo* study reported no significant difference in treatment outcome between the matched-single-cone and lateral compaction techniques after 6–18 months.[21]

These obviously inconsistent results may be due to the shape of original canal, the differences in specimen preparation, the experimental protocols, or storage conditions. The use of single-cone obturation should be limited to round canals, because in irregular-shaped canals the use of single cones may result in voids[22] or greater volumes of sealer.[9] Therefore, small diameter and minimally curved mesial and distal roots of upper molars and the mesial roots of lower molars would be appropriate for this technique. In this study, the techniques were practiced extensively beforehand, and all specimens were prepared and filled by one operator to reduce variability. In order to reduce the possibility of deformation or fracture, each instrument was used to prepare only three root canals, and the sectioning was performed under water-cooling. When cutting the teeth, smearing of the filling on the section surface might occur despite the fact that water-cooling was used. Unnoticed smearing might have influenced accurate measurement of small void areas. In the present study, distal root with one single root canal were selected, however, this may have variation is in terms of outline, running form circular to oval being more or less extended in a faciolingual aspect. This is the limitation of this study. However, the teeth were randomly selected for experimental groups.

The optimum obturation technique must be used to ensure the integrity of the root canal filling in the few apical millimeters, which is regarded as the most crucial factor in the success of endodontic therapy. In order to ensure the long-term success of endodontic treatment, the root canal system should be obturated effectively, both coronally and apically.

Conclusions

The distribution of the filling material was influenced by the preparation technique. Moreover, vertical compaction of warm GP achieves a better-quality filling in oval canals, than either matched-single-cone, the cold lateral compaction, or Thermafil techniques. Clinicians should be aware of the structure of the root canal before or during root canal treatment.

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Conflicts of interest

There are no conflicts of interest.

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