Clin Oral Invest (2012) 16:225–230
DOI 10.1007/s00784-011-0509-z

ORIGINAL ARTICLE

A comparative evaluation of gutta-percha filled areas in curved root canals obturated with different techniques

Edgar Schäfer · Birthe Nelius · Sebastian Bürklein

Received: 8 September 2010 / Accepted: 9 January 2011 / Published online: 20 January 2011

Abstract The aim of this study was to compare different obturation techniques in severely curved canals in terms of the percentage of gutta-percha filled area and voids. The obturation times and the incidence of extrusion of filling material were also compared. Curved root canals (curvature, 25–35°) of 48 extracted human teeth were enlarged with Mtwo rotary NiTi instruments and obturated as follows: Group A: 0.04/35 matched-single-cone; Group B: cold lateral compaction with 0.04/35 gutta-percha master cone; Group C: warm vertical compaction; Group D: lateral compaction with standardized gutta-percha master cone. In all groups AHPlus was used as sealer. The teeth were sectioned horizontally at 2, 3, 4, 6 and 8 mm from the apex. The total area of each canal segment was measured and the areas of gutta-percha, sealer and voids were converted to percentages of the total area. Data were subjected to the Kruskal–Wallis and post hoc Dunn test. Obturation times were compared using ANOVA and post hoc Student–Newman–Keuls test. The matched-single-cone obturation (group A) was significantly the fastest method while warm vertical compaction (group C) required significantly more time than all other techniques ($p<0.05$). No significant differences were obtained between the groups in terms of percentage of voids at any level ($p>0.05$). At all levels, groups B, C, and D produced significantly higher gutta-percha filled areas ($p<0.05$) and lower sealer-filled areas ($p<0.05$) than group A. No significant differences were found between groups B, C, and D ($p>0.05$) regarding gutta-percha and sealer-filled areas. Within the limitations of the in vitro study, it can be concluded that lateral compaction of greater taper gutta-percha cones is a fast and efficient method for obturation of curved canals.

Keywords Lateral compaction · Sealer · Single cone · Thermoplasticized gutta-percha · Warm vertical compaction

E. Schäfer (✉) · S. Bürklein
Central Interdisciplinary Ambulance in the School of Dentistry, University of Münster,
Waldeyerstr. 30,
D-48149 Münster, Germany
e-mail: eschaef@uni-muenster.de

B. Nelius
Hagen, Germany

Introduction

Besides proper cleaning and shaping of the root canal, obturation is required to impede the flow of microorganisms and toxins to the periapical tissue [1]. Several techniques have been developed to achieve an adequate three-dimensional obturation of the instrumented root canal [2]. The currently most accepted and common technique is the cold lateral compaction of gutta-percha in combination with a sealer [3–7]. Gutta-percha is dimensionally stable [8, 9], whereas some sealers shrink upon setting and dissolve over time [10–12]. Thus, the amount of sealer should be kept to a minimum and a maximum amount of gutta-percha packed into the canal should be aimed at [3, 13]. Therefore, the sealer should be found only in a thin layer between the gutta-percha and the canal wall [9, 14]. To achieve this goal, it has been suggested to use gutta-percha compaction techniques for obturation, as they maximize the volume of gutta-percha in the canal [15]. Hence, the assessment of the percentage of gutta-percha filled area (PGFA) in cross-sections of root canals is an accepted method to evaluate the quality of obturation [3, 7, 13–22].

Besides the classical cold lateral compaction technique and modifications of this method [3, 15], techniques have been introduced utilizing heat to gutta-percha in the canal.

One of the best-known techniques is the warm vertical compaction of gutta-percha, the Schilder technique [2]. Recently, it has been advocated to use gutta-percha cones that match the taper and the size of rotary nickel–titanium instruments [22, 23]. These gutta-percha cones having greater tapers should be used as a single-cone technique following rotary preparation using nickel–titanium instruments [22, 23]. Whether or not these matching gutta-percha cones should be used in a "single-cone technique" or in combination with accessory cones is currently open to question. Moreover, information whether these matching gutta-percha cones provide a seal equally to that obtained when employing the warm vertical compaction is scarce up to now.

The primary aim of the present study was to compare four different obturation techniques in severely curved canals instrumented with rotary nickel–titanium files in terms of percentage area of filling materials and voids at different levels of the root. Moreover, the obturation techniques were compared regarding the incidence of apical extrusion and obturation times.

Materials and methods

Selection of teeth

A total of 48 extracted human teeth with at least one curved root canal were selected. After coronal access, apical patency of the canal was checked. Working length (WL) was obtained by measuring the length of the initial instrument (size 10) at the apical foramen minus 1 mm. Only teeth with intact root apices, no visible signs of fractures or cracks (4× magnification), and whose canal width near the apex was approximately compatible with size 15 were included. This was checked with silver cones sizes 15 and 20 (VDW, Munich, Germany).

Standardized radiographs were taken prior to instrumentation with the initial file inserted into the canal. The tooth was placed in a radiographic mount made of silicone-based impression material (Silaplast Futur; Detax, Ettlingen, Germany) to maintain a constant position. The degree and the radius of canal curvature were determined using a computerized digital image processing system [24]. Only teeth whose radii of curvature ranged between 5.0 and 9.0 mm and whose angles of curvature ranged between 25° and 35° were included, and the distance between the apex and the cement–enamel junction (CEJ) was measured.

Root canal preparation

Only one canal was instrumented in each tooth. All canals were enlarged in the following sequence of Mtwo NiTi instruments (VDW) using the torque limited automated device Endo IT (VDW): 0.04/10; 0.05/15; 0.06/20; 0.06/25; 0.06/30; 0.04/35. All instruments were used to full WL. After each instrument, the canals were flushed with 5 mL of a 2.5% NaOCl solution using a 30-gauge needle (NaviTip, Ultradent, Munich, Germany). All preparations were completed by one operator. Before obturation, each canal was flushed with 10 mL EDTA (17%) to remove the smear layer and finally with 10 mL NaOCl then dried with paper-points.

Based on the degree and the radius of curvature and the distance between the CEJ and the apex, the teeth were allocated into four identical groups of 12 teeth. The homogeneity of the groups with respect to these three criterions was assessed using ANOVA and post hoc Student–Newman–Keuls test (Table 1).

Root canal obturation

Following root canal preparation, master cones were fitted with tugback at WL, were slightly coated with sealer and placed into the canal until WL. In all groups, AHPlus (DeTrey Dentsply, Konstanz, Germany) was used as sealer, and prior to obturation small amounts were applied to the canal using a K-file size 25 in a counter-clockwise rotation. Subsequently, different procedures were followed for each

Table 1 Characteristics of curved root canals (n=12 teeth per group)

Group	Curvature [°]			Radius [mm]			Distance CEJ-apex [mm]		
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
A	30.98	2.93	25.0–35.0	7.10	1.30	6.3–8.6	13.50	1.61	11–16
B	30.87	3.53	25.8–35.0	7.07	0.99	6.0–8.4	13.62	1.44	11.5–16.5
C	31.03	2.96	25.7–34.8	6.98	1.36	5.0–8.7	13.58	1.49	12–17
D	30.93	2.65	25.1–34.1	6.99	1.49	5.1–8.8	13.54	1.39	11–15.5
	p=1.000	p=0.995	p =1.000						

Group A: 0.04/35 matched-single-cone; Group B: lateral compaction with 0.04/35 gutta-percha master cone; Group C: warm vertical compaction; Group D: lateral compaction with standardized gutta-percha master cone

CEJ cement–enamel junction

group. All obturation were carried out by the same operator (SB) who was proficient in all the obturation techniques tested. Prior to this study the operator (BS) was trained in a pilot study to ensure that he was equally experienced in all the obturation techniques.

Group A: matched-single-cone obturation with a master cone (0.04/35 Mtwo gutta-percha, VDW) matching the final instrument used for preparation.

Group B: cold lateral compaction with a master cone (0.04/35 Mtwo gutta-percha) matching the final file used for preparation. A size 25 NiTi finger spreader was introduced for the first time to 2 mm short to WL. Sealer-coated 0.02/20 accessory cones (VDW) were used for lateral compaction. As many accessory cones as possible were placed into the canals until the same level (8 mm from the apex) was reached.

Group C: warm vertical compaction using Machtou NiTi- (size 0) and stainless steel pluggers (sizes I–IV; all VDW) for the down-pack and Beefill (VDW) for the backfill. The tip of a size 35 standardized gutta-percha cone (VDW) was trimmed back (shortened at the tip by 0.5–1 mm) until tugback was achieved at WL. Heated pluggers (using a Bunsen burner flame) were used for compaction of the primary gutta-percha cone in the apical portion of the canals. Apical pressure with the pluggers was applied until a distance of 3–5 mm of the WL was reached. The coronal portion of the canal was obturated using thermoplasticized gutta-percha (Beefill, set to 180°C), which was vertically condensed in 2–3 mm increments with hand pluggers.

Group D: cold lateral compaction with standardized gutta-percha cones (0.02/35; VDW). Lateral compaction was performed as described for group B.

A heated plugger was used to remove the coronal excess gutta-percha with no further vertical compaction. Teeth were stored for 14 days at 37°C and 100% humidity to allow the sealer to set completely. The time required for total obturation was recorded and any extrusion of filling material (sealer and/or gutta-percha) was noted using a yes/no scheme. No further assessment regarding the quantity of extruded material was made.

The teeth were embedded in resin blocks (Technovit, Heraeus-Kulzer, Wehrheim, Germany) and sectioned horizontally with a 0.1-mm-low-speed saw (Leitz, Wetzlar, Germany) under water-cooling at 2,3,4,6, and 8 mm from the apex. Sections were photographed at 20× magnification with a digital camera (Minolta dynax, Leitz, Wetzlar, Germany) using a stereomicroscope (Leica, Wetzlar, Germany). On these digital images of each segment, the total area of each canal segment and the areas of its contents (gutta-percha, sealer, voids) were measured in a metric system using the ImageJ software (National Institute of Health, public domain). The area of gutta-percha, sealer and voids were converted to percentages of the total area. The analysis of these cross-sections was made by a second examiner who was blind in respect of all experimental groups. For each section, measurements were repeated three times and the means were calculated.

The average area values of each section for each filling component were compared for the groups. As data were not normally distributed (Kolomogorov–Smirnov test), they were subjected to the nonparametric Kruskal–Wallis test and post hoc Dunn test. The incidence of apical extrusion was analyzed using the Chi-square test. No further differentiation between extruded sealer and/or gutta-percha was made. Obturation times, which were normally distributed, were compared using ANOVA and post hoc Student–Newman–Keuls test. The level of significance was set at $p<0.05$.

Results

Statistical analysis revealed that the groups were well-balanced concerning the parameters degree and radius of curvature and the distance CEJ-apex (Table 1).

The results for gutta-percha, sealer and voids ratios in each section are summarized in Table 2. No significant differences were obtained between the groups in terms of percentage of voids at any level ($p>0.05$). At all levels, groups B, C and D produced significantly higher PGFA ($p<0.05$) and lower sealer-filled areas ($p<0.05$) than group A. No significant differences were found between groups B, C, and D ($p>0.05$). In all groups, the PGFA increased and the area of sealer decreased steadily from the apical to the coronal section.

The mean time taken to obturate the canals is shown in Table 3. The matched-single-cone obturation (group A) was significantly faster than the other techniques ($p<0.05$). The use of matching gutta-percha cones in combination with lateral compaction (group B) was significantly faster than lateral compaction using standardized gutta-percha cones (group D) and warm vertical compaction (group C), which required significantly more time than all other techniques ($p<0.05$; Table 3).

A significant higher incidence of extrusion of filling material (Table 3) was recorded for the warm vertical compaction compared with the matched-single-cone technique ($p<0.05$). All other differences were not statistically different ($p>0.05$).

Discussion

Experimental setup

Most sealers shrink upon setting and dissolve over time [10–12], whereas gutta-percha is known to be dimensionally stable [8, 9]. Therefore, the PGFA has been used to

Table 2 Mean and standard deviation of gutta-percha-filled area (GP), sealer and voids ratios of the five groups (%): Group A: .04/35 matched-single-cone; Group B: lateral compaction with .04/35 gutta-percha master cone; Group C: warm vertical compaction; Group D: lateral compaction with standardized gutta-percha master cone

Group	2 mm			3 mm			4 mm			6 mm			8 mm		
	GP	Sealer	Voids	GP	Sealer	Voids	GP	Sealer	Voids	GP	Sealer	Voids	GP	Sealer	Voids
A	61.14±14.08 a	55.88±14.57 a	2.98±3.08	67.29±8.14 a	28.55±7.35 a	4.15±3.85	71.07±7.24 a	24.98±5.77 a	3.94±2.52	75.41±7.99 a	22.27±8.49 a	2.31±1.93	83.60±5.91 a	12.95±5.83 a	3.45±2.90
B	76.24±6.99 b	19.10±6.10 b	4.25±3.70	78.78±9.61 b	15.58±9.65 b	4.39±3.74	84.57±7.26 b	12.31±4.85 b	3.45±5.40	90.96±3.56 b	5.04±3.02 b	3.93±2.58	93.42±2.74 b	3.50±3.48 b	3.04±2.28
C	78.71 ± 7.45 b	16.64 ± 7.18 b	4.65 ± 3.87	79.68 ±10.74 b	17.89 ± 9.86 b	3.34 ± 3.26	85.52 ± 9.62 b	12.18 ± 8.48 b	2.47±2.48	90.32±4.54 b	5.52±3.42 b	4.16±2.53	92.1±4.67 b	5.21±3.27 b	2.68±2.58
D	80.05±9.13 b	16.88±8.20 b	3.04±3.46	82.03±5.63 b	14.34±6.58 b	3.62±2.99	86.63±5.81 b	10.30±4.82 b	3.16±3.00	90.83±3.98 b	5.95±3.79 b	3.21±1.83	93.00±2.47 b	3.13±2.18 b	3.86±3.03
	$p<0.001$	$p<0.001$	$p=0.440$	$p<0.001$	$p<0.001$	$p=0.560$	$p<0.001$	$p<0.001$	$p=0.532$	$p<0.001$	$p<0.001$	$p=0.342$	$p=0.001$	$p<0.001$	$p=1.154$

Values with the same letters were not statistically different at $p=0.05$

Table 3 Mean obturation time and standard deviation with the different techniques and number of canals showing extrusion of filling material

Group	Time [s]		Extrusion of filling material
	Mean	SD	Number of canals
A	44.00 a	4.32	1
B	105.25 b	4.45	5
C	259.08 d	15.35	9
D	180.50 c	15.61	4
	$p<0.05$	$p=0.021$	

Group A: 0.04/35 matched-single-cone; Group B: lateral compaction with 0.04/35 gutta-percha master cone; Group C: warm vertical compaction; Group D: lateral compaction with standardized gutta-percha master cone. Values with the same letters were not statistically different at $p=0.05$

evaluate the quality of obturation in numerous studies [3, 7, 13–23, 25–27]. While most of these studies evaluated obturation of straight canals [3, 13, 14, 18, 20, 23, 25, 26] data regarding the quality of obturation of severely curved canals is limited [21, 22, 27]. Moreover, some investigations aimed at a comparison of different preparation-filling combinations [13, 19, 25], while in the present study the ability of different obturation techniques was analyzed using severely curved canals, all of them instrumented with the same preparation technique.

In the present study, Mtwo instruments were selected for preparation as matching gutta-percha cones for these instruments have been introduced by the manufacturer recently, but up to now no information regarding the quality of obturation they provide is available. Mtwo files have been reported to be safe and respect canal curvature very well even in severely curved root canals [28].

The methodology used in the present study is based primarily on measurements of filled canal areas and voids. When evaluating the obtained results, it should be taken into consideration that this method, although used frequently in previous studies [13–23, 25–27], has some immanent weaknesses. 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. Moreover, when using sliced sections only two-dimensional assessments of void areas can be made. Thus, in order to overcome these shortcomings, the additional use of non-destructive scans of the teeth would be beneficial.

Due to these limitations of the methods and in view that the present study is presenting in vitro results, the extrapolation of the results obtained to the clinical performance of the different obturation methods must be taken with the utmost caution.

Principal findings

Similar percentages of gutta-percha and sealer-filled areas were found in canals filled either with lateral compaction of matched gutta-percha cones, warm vertical compaction and lateral compaction of standardized gutta-percha cones at all levels evaluated, while single cone obturation resulted in significantly lower values for gutta-percha and higher for sealer-filled areas (Table 2). These findings agree with those of a previous study [29] in which matching gutta-percha cones were found to be more efficient in obturating straight canals enlarged with rotary NiTi instruments than standardized gutta-percha cones but are in contrast with other reports [22, 23]. In the latter studies, curved [22] as well as straight canals [23], were instrumented either with ProFile [22] or ProTaper instruments [23] (both Maillefer, Ballaigues, Switzerland) and obturated with matching single cones. No significant differences between laterally compacted and single-cone gutta-percha were detected at any level. These differences can be attributed to the fact that straight [23] and less curved canals (19.7°–25.6°) [22] were used, while in the present study mean curvatures ranged between 30.87°–31.03° (Table 1). Moreover, it is currently unknown in how far the Mtwo gutta-percha cones correspond perfectly with the Mtwo instruments regarding taper and diameter. Finally, other factors affecting results (e.g., root canal shape and operator variability) limit direct comparison between these different studies [23].

The mean PGFA in canals belonging to groups B–D ranged between 76.2% and 93.4% while for canals filled with single cones PGFA ranged between 61.1% and 83.6%. Similar values have been reported in earlier studies [13, 17, 23]. Also, the obvious trend for increase of PGFA from apical to coronal direction corroborates with previous reports using the same filling techniques [13, 22].

Single-cone obturation was significantly the fastest technique followed by lateral compaction of 0.04 taper Mtwo gutta-percha cones, which was significantly faster than the other techniques (Table 3). This finding is in agreement with previous reports [22, 23]. The two most time-consuming techniques were cold lateral and warm vertical compaction, as already reported previously for the lateral compaction technique [13]. The reason why warm vertical compaction took significantly more time than cold lateral compaction might be because the pluggers were heated using a Bunsen burner flame. It can be assumed that using an electric heat carrier would have resulted in markedly shorter obturation times.

No significant differences regarding gutta-percha and sealer-filled areas were obtained between these two techniques at any level (Table 2), which is in agreement with the findings of other studies [3, 13, 17].

Conclusion

Under the condition of this in vitro study, it appears that the use of matching Mtwo gutta-percha cones in combination with cold lateral condensation of standardized accessory cones seems to be a suitable alternative for obturation of curved canals compared to cold lateral compaction of standardized gutta-percha cones and warm vertical compaction.

Conflict of Interest The authors declare that they have no conflict of interest.

References

1. Mollander A, Reit C, Dahlén G, Kvist T (1998) Microbiological status of root-filled teeth with apical periodontitis. Int Endod J 31:1–7
2. Schilder H (1967) Filling root canals in three dimensions. Dent Clin North Am 11:723–744
3. Jarrett IS, Marx D, Covey D, Karmazin M, Lavin M, Gound T (2004) Percentage of canals filled in apical cross sections—an in vitro study of seven obturated techniques. Int Endod J 37:392–398
4. Gilhooly RM, Hayes SJ, Bryant ST, Dummer PM (2000) Comparison of cold lateral condensation and a warm multiphase GP technique for obturating curved root canals. Int Endod J 33:415–420
5. Gulabivala K, Holt R, Long B (1998) An in vitro comparison of thermoplasticised gutta-percha obturation techniques with cold lateral condensation. Endod Dent Traumatol 14:262–269
6. McMurtrey LG, Krell KV, Wilcox LR (1992) A comparison between Thermafil and lateral condensation in highly curved canals. J Endod 18:68–71
7. De-Deus G, Reis C, Beznos D, Gruetzmacher de Abranches AM, Coutinho-Filho T, Pactornik S (2008) Limited ability of three commonly used thermoplasticized gutta-percha techniques in filling oval-shaped canals. J Endod 34:1401–1405
8. Brayton SM, Davis SR, Goldmann M (1973) Gutta-percha root canal fillings: an in vitro analysis—part 1. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 35:226–231
9. Wu MK, Özok AR, Wesselink PR (2000) Sealer distribution in root canals obturated by three techniques. Int Endod J 33:340–345
10. Kontakiotis EG, Wu MK, Wesselink PR (1997) Effect of sealer thickness on long-term sealing: a 2-year follow-up study. Int Endod J 30:307–312
11. Schäfer E, Zandbiglari T (2003) Solubility of root canal sealers in water and artificial saliva. Int Endod J 36:660–669
12. Kazemi RB, Safavi KE, Spangberg LSW (1993) Dimensional changes of endodontic sealers. Oral Surg Oral Med Oral Pathol 76:766–771
13. Keçeci AD, Çelik Ünal G, Şen H (2005) Comparison of cold lateral compaction and continuous wave of obturation techniques following manual or rotary instrumentation. Int Endod J 38:381–388
14. Gulsahi KG, Cehreli ZC, Onay EO, Tasman-Dagli F, Ungor M (2007) Comparison of the area of resin-based sealer and voids in roots obturated with Resilon and gutta-percha. J Endod 33:1338–1341

15. Souza EM, Wu MK, van der Sluis LW, Leonardo RT, Bonetti-Filho I, Wesselink PR (2009) Effect of filling technique and root canal area on the percentage of gutta-percha in laterally compacted root fillings. Int Endod J 42:719–726
16. Ordinola-Zapata R, Bramante CM, de Moraes IG, Bernardineli N, Garcia RB, Gutmann JL (2009) Analysis of the gutta-percha filled area in C-shaped mandibular molars obturated with a modified MicroSeal technique. Int Endod J 42:186–197
17. De-Deus G, Gurgel-Filho ED, Magalhães KM, Coutinho-Filho T (2006) A laboratory analysis of gutta-percha-filled area obtained using Thermafil, System B and lateral condensation. Int Endod J 39:378–383
18. James BL, Brown CE, Legan JJ, Moore BK, Vail MM (2007) An in vitro evaluation of the contents of root canals obturated with gutta-percha and AH-26 sealer or Resilon and Epiphany sealer. J Endod 33:1359–1363
19. Ardila CN, Wu MK, Wesselink PR (2003) Percentage of filled canal area in mandibular molars after conventional root-canal instrumentation and after noninstrumentation technique (NIT). Int Endod J 36:591–598
20. Wu MK, van der Sluis LWM, Wesselink PR (2002) A preliminary study of the percentage of gutta-percha-filled area in the apical canal filled with vertically compacted warm gutta-percha. Int Endod J 35:527–535
21. Pagavino G, Giachetti L, Nieri M, Giuliani V, Scaminaci Russo D (2006) The percentage of gutta-percha-filled area in simulated curved canals when filled using Endo Twin, a new heat device source. Int Endod J 39:610–615
22. Gordon MP, Love RM, Chandler NP (2005) An evaluation of.06 tapered gutta-percha cones for filling of 0.06 taper prepared curved root canals. Int Endod J 38:87–96
23. Romania C, Beltes P, Boutsioukis C, Dandakis C (2009) Ex-vivo area-metric analysis of root canal obturation using gutta-percha cones of different taper. Int Endod J 42:491–498
24. Schäfer E, Vlassis M (2004) Comparative investigation of two rotary nickel-titanium instruments: ProTaper versus RaCe. Part 2. Cleaning effectiveness and shaping ability in severely curved root canals of extracted teeth. Int Endod J 37:239–248
25. van der Borden WG, Wu MK, Wesselink PR (2010) Percentages of gutta-percha-filled canal area observed after increased apical enlargement. J Endod 36:139–142
26. Wu MK, de Groot SD, van der Sluis LWM, Wesselink PR (2003) The effect of using an inverted master cone in a lateral compaction technique on the density of the gutta-percha fill. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 96:345–350
27. VanGheluwe J, Wilcox LR (1996) Lateral condensation of small, curved root canals: comparison of two types of accessory cones. J Endod 22:540–542
28. Schäfer E, Erler M, Dammaschke T (2006) Comparative study on the shaping ability and cleaning efficiency of rotary Mtwo instruments. Part 2. Cleaning effectiveness and shaping ability in severely curved root canals of extracted teeth. Int Endod J 39:203–212
29. Hembrough MW, Steiman HR, Belanger KK (2002) Lateral condensation in canals prepared with nickel-titanium rotary instruments: an evaluation of the use of three different master cones. J Endod 28:516–519