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Original

In-vitro evaluation of the effect of canal curvature on adaptation of gutta-percha in canals obturated with HEROfill system by CBCT

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Abstract: A hermetic seal of the root canal space following canal preparation is important in endodontics. This study evaluated the effect of canal curve on adaptation of gutta-percha to dentinal walls of canals obturated using the Herofill system. For this *in vitro* study, 80 mesial roots of mature human first molars with length of 16 mm, curve between 5° and 45°, and no caries or resorption of the root surface were selected. A cone beam computed tomography system was used to evaluate the presence or absence of a gap in the samples. Photographs were taken in three sections: 2 mm above the curve, at the curve and 2 mm below the curve. The gap area was identified using Photoshop and AutoCAD software. Kruskal Wallis and Mann-Whitney tests were used to analyze the data mounted in a castcurve. There were significant differences between the two lateral condensation groups with various curves; roots with more curve had more gaps. When the Herofill and lateral condensation groups were compared without considering the sections and curve, there was a significant difference between these groups and the Herofill group had less gaps. The Herofill system is an alternative to the lateral condensation technique in severely curved canals. (J Oral Sci 53, 43-50, 2011)

Keywords: Herofill system; lateral condensation; canal curve.

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Introduction

Endodontic treatment involves cleaning and shaping of the root canal and three-dimensional (3D) sealing of the canal space. For successful root canal treatment, the canal must be cleaned well, prepared, and filled completely (1,2). Sealing the canal properly increases the clinical success rate to approximately 96.5% (3). The cause of nearly 60% of endodontic failures is incomplete and improper root canal filling (4). Schilder stated, “Canal filling should include the entire root canal and accessory and lateral canals” (5,6). Some of the most important factors that affect quality of root canal treatment are the anatomy of the canal, the presence of extra canals, and curve in the canal pathway (6,7).

Root canal treatment of teeth with severe curve is complicated, and facilitating treatment is a clinical challenge. Studies of different techniques of obturation and their efficiency have been performed. Some investigators found that techniques using a carrier were better than the conventional method of lateral condensation. On the other hand, it appears that there is a possibility of separation of gutta-percha from the carrier in canals with severe curves in core carrier systems, and the filling material does not adapt to canal walls adequately.

Several methods have been applied to evaluate adaptation of gutta-percha to canal walls, including evaluation of histological sections, clearing, evaluation of density of obturation by spreader penetration, evaluation of quality of obturation with radiographs, imaging of bioluminescence bacteria, and the newest method of evaluation, the CT scan. Advantages of the CT scan include convenience, decreased examination time, lack of removal of dental tissue, lack of damage to samples, possibility of examination of any section of the canal, and repeatability.

In the present study, the effect of canal curvature on quality of obturation by the Herofill carrier system was evaluated with the application of cone beam computed tomography (CBCT), which has a higher spatial resolution in comparison to CT tests, and is one of the most precise devices available.

Materials and Methods

We selected 80 mesial roots of human first molars for this *in vitro* study. These roots had mature apices, a curve between 5° and 45°, and no caries or resorption on the root surface. Cases with bayonet curve or an apparent curve in more than one direction in the root were excluded. The surfaces of the roots were cleaned with a periodontal curet to remove calculus and soft tissues, and afterward, they were kept in sodium hypochlorite (NaOCl) for 1 h and then in normal saline for the remainder of the test. The mesiobuccal roots of all the teeth were separated.

The crowns of the teeth were removed with a multi-purpose bur and high-speed handpiece so that the length of roots was adjusted to approximately 16 mm. If necessary, an access cavity was prepared and patency was checked with file #10 or #15. In all samples, the canal straightner in buccolingual orientation was used. The angle and radius of canal curve was determined with AutoCAD software using the Pruett method (8,9). The root canals were divided into 4 groups of 20 each based on angle and radius of curve. In the A and B groups, the angle of curve was <25°. In the C and D groups, it was >25° and <45°.

After determination of the curve of roots, the working length was measured by passing #10 flexofile (Dentsply, Maillefer, instruments SA, Ballaiguse, Switzerland) carefully along the canal until the tip was just visible at the apical foramen. This length was recorded, and 1 mm was subtracted to obtain the working length. All root canals were prepared by one operator. In all samples, the root canal system was prepared with the HERO Shaper system (Micro-Mega, Besancon, France), according to the recommended protocol of the manufacturer. In canals with intermediate curve, HERO Shaper file #25/6% in two-thirds of the working length was used. Subsequently, HERO Shaper files #25 and #30/4% in the working length were used. In canals with severe curve, HERO Shaper file #20/6% in two thirds of the working length was applied, followed by HERO Shaper files #20, #25, and #30/4%.

The canal was irrigated with 1 ml of sodium hypochlorite 2.5% after application of each file. At the time of canal preparation, each file was soaked in RC prep (Premier, PA, USA) before inserting it into the canal. After application of each file, the patency was checked with K file #10. Rotation time of each file in the canal was 5 – 10 s; a light force was applied, with a 2-3 mm pecking movement throughout the stages. Preparation included the electromotor (Tc motor 3000) and potency reducer handpiece 16:1 (WH975, Dental work, Burmoos Austria) with a rate of 450 rpm. The smear layer was removed from all specimens by irrigating with 17% EDTA solution (Pulpdent, Watertown, MA) and a 5.25% NaOCl solution. The canals were washed thoroughly with distilled water delivered in a disposable endodontic syringe with a 27-gauge needle; canals were then dried with paper cone (DENTSPLY, Maillefer, Switzerland).

The roots with a curve <25° were divided randomly into two groups, A and B, and the roots with a curve >25° and <45° were divided randomly into two groups, C and D (each group consisted of 20 teeth).

In group A, canals were filled with Herofill obturators (size 30). Initially, a thin layer of AH-26 sealer (DeTrey, Dentsply, Konstanz, Germany) was placed in the coronal portion of the canals using a size 30 verifier; Herofill obturators were heated in a particular oven for 60 s and then placed in the entire working length. The handle of the obturators and excess material were cut with a small round bur (Thermacut, Dentsply).

In group B, canals were filled using the lateral condensation technique. A size 30 gutta-percha cone (Dentsply Lexicon, Tulsa, OK) was dipped in AH-26 sealer and placed in the canal as master cone and condensed with the appropriate spreader (at apical portion, finger spreader size A and at coronal two-third portion size B (Dentsply). Accessory gutta-percha cones (size 20) were placed beside the master cone until accessory cones could not be inserted more than 3 mm into the canal. After the entire canal was filled, the extra gutta-percha was removed with a hot instrument just below the orifice, and the remainder was condensed vertically with a small plunger.

Samples in group C were filled with size 30 Herofill obturators as in group A. Canals of group D were filled using the lateral condensation technique as in group B. To evaluate samples using CBCT, samples were placed in plaster casts. For this purpose, a mixture of 5 units of sawdust and 2 units of white plaster was used to create a product similar to spongy bone. A thin layer of melted red wax was applied peripheral to the root of the tooth to indicate periodontal ligament space. Finally, to simulate an environment similar to the soft tissue surrounding the dentition, casts were placed in water in an appropriate container.

To ensure that the teeth were arranged parallel to the surface, the orientation of placement of teeth was defined in a cast using a surveyor, and then the teeth were placed in cavities made by an acryl-cutter handpiece (with the same depth and parallel to each other). The samples dipped in wax were placed in these cavities and, for elimination of space between tooth and cavity, plastered with a thin consistency of the aforementioned sawdust/plaster formula.

The CT-scan set applied for this project was a high resolution, Planmeca promax 3D-type CBCT system. The detector of the system is a flat panel type that includes CMOS and cesium iodide scintillator. This system is capable of taking images of 0.1 mm thickness with a spatial resolution of 3.2 pair lines.

For image scanning, the system was used with the following conditions: MA: 5 / Kvp: 64/resolution: 3.2 (high)/scan time: 12.5 s/useful scan time: 3.5 s/matrix size: 1024/thickness: 0.1 mm/space interval: min 0.1 mm.

After taking scans in the axial, coronal, and sagittal directions, the images of the sections were examined for gaps by a radiologist and endodontist, who were unaware of the study protocol (Fig. 1). For determination of the curve limit zone, the crossing point of two lines when determining curve by the Pruett method was considered as a curve site. If a gap was seen in the axial section, its presence was confirmed in other sections.

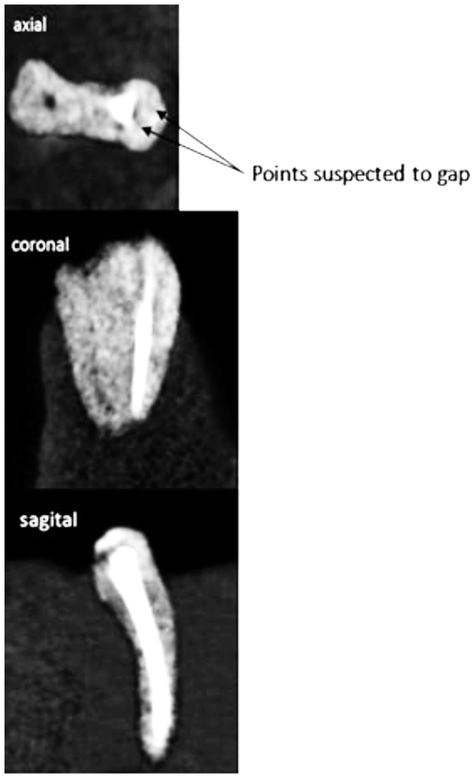

Fig. 1 Prepared scan model from a sample with an artifact at the curve section in three views: the axial, sagittal, and coronal (ignoring the gap in the upper views).

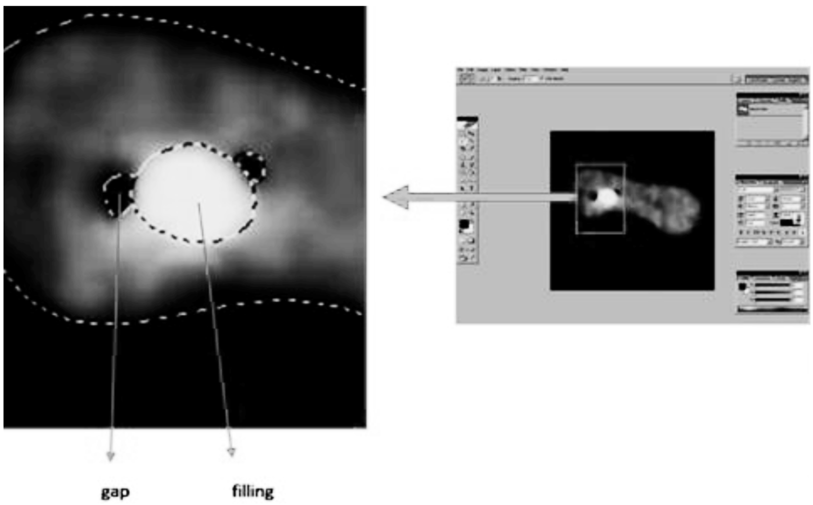

Fig. 2 Scanning an image using Photoshop software.

Images scanned by CBCT were exported as JPEG images with high contrast in samples with gaps and periphery of the gap point was recognized in CS4 Photoshop (Fig. 2). Afterward, they were exported to the illustrator program for conversion into calculable diagrams and then exported to the Auto CAD 2009 program for precise calculations of perimeter and area (Fig. 3). A specific definition for area was required to convert data to exact units, and this action was performed on one of the teeth with calipers (by measurement of tooth dimensions) and defined for software.

Results

After examining all groups at different sections with two curves, the amount of incoherence of filling material with the canal wall was observed.

1. In groups with curve <25°, the largest gap area (0.0583 mm^2) was seen in the lateral condensation group sectioned 2 mm above the curve, and the least average gap was in the Herofill group sectioned 2 mm above the curve (0.0018 mm^2).
2. In groups with curve >25°, the largest gap area (0.0746 mm^2) was seen in the lateral condensation group sectioned 2 mm below the curve. However, the average gap was least in the Herofill group sectioned 2 mm below the curve (0.0144 mm^2), and that in the lateral condensation group sectioned 2 mm below the curve (0.0321 mm^2) was the greatest.

   Because distribution of data was not normal, the Kruskal Wallis test was used for comparison of medians and for cases in which a significant difference resulted ($P < 0.05$), the Mann-Whitney test was applied for a two by two comparison between groups.
3. On comparison of medians of sections 2 mm above the curve, there was no significant difference between the four groups ($P = 0.094$).

   Comparison of groups sectioned at the curve showed significant difference ($P = 0.002$).
4. On comparing the two lateral condensation groups with different curves, there was a significant difference between gap areas of sections 2 mm below the curve ($P = 0.004$).
5. On comparing the two groups of lateral condensation and Herofill with a curve >25°, there was a significant difference between gap areas of sections 2 mm below the curve ($P = 0.024$). (Table 1)

For comparison of four groups regardless of the studied sections, Kruskal Wallis test was used for medians and when there was a significant difference, Mann-Whitney test was applied for two-by-two comparison between groups. When a $P = 0.001$ was considered significant, there was significant difference between the four groups, and the Herofill group with curve <25° showed the least gap. (Table 2)

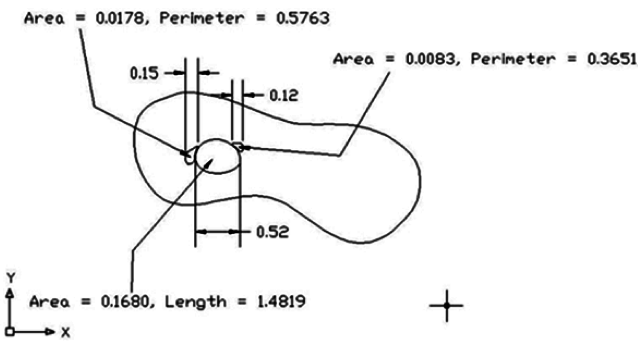

Fig. 3 Calculation method of the areas.

Table 1 Comparison of the two lateral condensation and Herofill groups with curves above 25° sectioned 2 mm below the curve

Curve	Group	Number	Average (mm^2)	Mean rank	*P* Value
Above 25°	Herofill	20	0.0144	16.60	0.024
	Lateral condensation	20	0.0321	24.40	

Table 2 Comparison of medians of the dependent variable (gap) regardless of the studied section in the four groups

Curve	Group	Number	Average (mm^2)	Mean rank	*P* Value
Under 25°	Herofill	20	0.0026	29	0.001
	Lateral condensation	20	0.0103	38.48	
Above 25°	Herofill	20	0.0105	40.38	
	Lateral condensation	20	0.0259	54.15	

Table 3 Comparison of medians in the dependent variable (gap) regardless of the studied sections and curve in two Herofill and lateral condensation groups

Group	Number of all sections	Mean rank	*P* Value
Herofill	120	106.38	0.000
Lateral condensation	120	134.62	

Table 4. Comparison of the average (gap) regardless of the studied sections and curve in two Herofill and lateral condensation groups

Filling technique	Number of all sections	Min	Max	Average (mm^2)
Herofill	120	0	0.0744	0.008853
Lateral condensation	120	0	0.0743	0.0181

Comparison of the groups regardless of the curve and studied sections showed a significant difference between two groups ($P = 0.000$). (Table 3) Gap averages regardless of the studied sections and curve were less in the Herofill group. The difference between the two groups was significant ($P = 0.000$). (Table 4)

Discussion

The present *in vitro* study evaluated the impact of canal curvature on gutta-percha adaptation in canals filled using the Herofill system. Three-dimensional obturation of a root canal is critical for success of endodontic treatment, and microleakage is the main cause of endodontic failure regardless of the applied filling technique. Microleakage is a pathway through the root structure and filling material for bacteria, fluid, and chemical material, which occurs due to residual microscopic gaps at the interface of the filling material and tooth (10-12).

This study noted the effect of canal curvature on adaptation of gutta-percha because according to many studies, canal filling techniques, irregularity of the root canal, and presence of a curve in the root canal affect sealing and adaptation of gutta-percha (13-16).

While evaluating the effect of curve on two lateral condensation and Thermafil systems, EL Deeb et al. concluded that lateral condensation resulted in a better seal in straight canals, while in curved canals, the seal was not appropriate. Overall, the Thermafil system provided a better seal in curved canals (15). However, according to Leung and Gulabivala, who evaluated the effect of curve on the sealing ability of Thermafil, there was no significant difference between the two techniques, regardless of the presence of a curve (12).

In the present study, the mesial roots of molar teeth with a curve angle under and above 25° were evaluated similar to the studies by Leung and Gulabivala (12) and McMurtrey et al. (16)

The Pruett method (8,9) was used to determine the curve. In his article, Pruett stated that the Schneider method considers only the beginning point of curve and terminal point (the apical foramen), which are joined to each other, and he did not take into account the amount of curve present between these two points.

Most studies have concluded that the lateral condensation technique is suitable for straight canals (17-20), but the problem of obturation of curved canals has remained immutable. In such cases, one of the recommended techniques in addition to injecting systems is the use of a core carrier system. In this study, the lateral condensation technique was chosen because it is the most commonly used method and standard in most comparative studies (13,16,17,21,22).

Gulabivala et al. (17) and McMurtrey et al. (16) have evaluated the efficiency of Thermafil in canals with severe curves. They compared the effect of a curve (in canals above 25°) on microleakage in two Thermafil and lateral condensation systems and found that Thermafil was more efficient in canals with severe curves. Because it is less expensive and more widely available, Herofill was selected for this study. Herofill is an easy and rapid system compared to the current lateral condensation systems, and it is similar to Thermafil systems in terms of the application method and structure of its components (20,21).

In the present study, CBCT was employed to evaluate the presence of a gap. The CBCT is non-aggressive and requires less working time, whereas in histologic examination and evaluation of marginal integrity by SEM methods, gutta-percha may melt during cutting of samples and thus decrease the accuracy of studies (23). Using the radiographic method, samples were evaluated two-dimensionally, and three-dimensional analysis was possible without damaging them using the CT scan. This method allows later evaluation of the performance of the samples. According to Jung and Lommel and Von Stechow et al., the accuracy of micro-CT is comparable to histologic sections. In this study, CBCT, one of the best devices in terms of spatial resolution, was used (23,24).

Other advantages of CBCT system include feasibility of three-dimensional evaluation of samples to ascertain the presence of a gap between gutta-percha and canal walls. However, CT images actually provide a radiographic appearance of the sample and do not determine the boundaries of the gap with 100% accuracy. Therefore, in this study, to address this problem, we increased image contrast to differentiate the filling and then magnify the gap, which was analyzed by the software. It should also be noted that the CBCT technique is more efficient in determining the presence of a gap rather than the actual amount of gap area. However, determining the presence of a gap is what lends validity to this study.

In this study, the adaptation of gutta-percha to the canal walls was evaluated in three sections: 2 mm above the curve, curve limit, and 2 mm under the curve. The purpose in selecting these sections was to obtain more accurate measurements than evaluation of the confines of the curve. There was no statistically significant difference between the four groups when comparing the lateral condensation group and Herofill group with different curves sectioned 2 mm above the curve, which is probably due to the presence of a straight canal above the curve. This finding is consistent with results reported by Boussetta et al. in terms of microleakage (by a dye penetration technique); there was no significant difference between the Herofill group and lateral condensation group (20).

However, the importance of the adaptation of filling material to the walls throughout the canal length is a proved and evident actuality (20,25-27). If data were available regarding the sealing ability of any one canal obturation system based on adaptation in straight canals in relation with technique (more leakage of a filling because of the presence of empty spaces between the filling and canal space), the results of the present study could be discussed in comparison with the previous studies (15,17-20).

Our result conforms to the study by Boussetta et al. which evaluated microleakage using the dye penetration technique because in their study the amount of microleakage was less in the Herofill group sectioned 0.5 mm above the working length (1 mm short of the apical foramen) (20). In the study by De Moor et al. which compared apical microleakage in three systems, thermomechanical, lateral condensation and Herofill, using the dye penetration technique, the Herofill group had the most microleakage. This difference could be due to an inadequate K-file canal preparation technique, which resulted in inadequate preparation of the coronal portion of the root for proper penetration of the Herofill system (21).

When the two Herofill and lateral condensation groups with curve above 25° sectioned 2 mm below the curve were compared, the amount of gap was less in the Herofill group. This indicates better efficiency of the Herofill system in canals with severe curve.

When comparing two groups using the lateral condensation system sectioned at the curve and 2 mm below the curve, the group with a curve >25° had more gaps; this is in agreement with previous studies regarding the inefficiency of the lateral condensation technique in canals with severe curve (13,19,20).

It was observed in some results of the present study that although the P-value was not significant, the resultant number was very close to becoming significant – that is, 0.05; therefore, it appears that if the sample size was larger, the results may have become significant.

Contradiction or conformity between similar studies and the present study might be due to the evaluation method of adaptation, especially in studies that used the dye penetration technique, which is not accurate in relation to current methods. In addition, most of them (except the study by Boussetta et al. (20)) used the Thermafil system which itself presents difficulties. In a study by Wesselink and Fan (25), which focused on the effect of curve in the apical portion of curved roots with a 21-40° curve in two Thermafil and warm vertical condensation systems by the fluid filtration method, there was less microleakage in the warm vertical condensation group at 3 mm of the apical zone in comparison to the Thermafil group. The carrier technique was weaker because the control group used the warm vertical condensation, which had a better sealing ability.

Most studies indicated that the exit of gutta-percha in relation to core carrier systems causes an increase in microleakage (28,29); with respect to this matter, in preparation of our samples, we attempted to stop at the apical zone to prevent this occurrence. As a result, we only had exit of gutta-percha in 3 of 80 samples.

Another issue in relation to core carrier systems is the separation of the carrier from gutta-percha (29); however, in later studies, it was proven that this event does not have an important effect on apical microleakage (22). Per this study's evaluation method, there was no feasibility of investigation into this matter because both gutta-percha and carrier are opaque.

Considering the importance of the influence of curve on the quality of canal filling (13,17,18), the method of the present study – in addition to reaffirmation of this matter and verification of reduction of adaptation of the filling with an increase of canal curve (especially in the lateral condensation technique) – provided the possibility of another comparative evaluation. That evaluation would be in terms of microleakage along the filling and the evaluation of its relation to the adaptation of filling due to maintenance and non-destruction of the samples, which promotes the value of the present study.

The Herofill system is a competent alternative to the lateral condensation technique in severely curved canals.

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