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Effect of filling technique and root canal area on the percentage of gutta-percha in laterally compacted root fillings

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Abstract

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Aim To determine the influence of filling technique and root canal area on the percentage of gutta-percha (PGP) in laterally compacted root fillings.

Methodology Sixty extracted canine teeth were accessed and the root canals instrumented to the same size. They were then divided in three groups and filled with laterally compacted gutta-percha cones and AH Plus using different techniques. A variation of cold lateral compaction using a sequence of spreaders prior to accessory cone placement was compared to two commonly-used techniques. Twenty additional canines with prepared root canals were used as negative controls in which gutta-percha was introduced into the canals but no compaction applied. The roots were sectioned horizontally at 3 and 6 mm from the apex and micro-photographs taken. Using software, the area of the canals and gutta-percha at each level were measured and PGP calculated. A Multivariate analysis was used to determine the variables influencing PGP. A linear regression test was used to verify the variation in PGP explained by canal area.

Results At each level the largest canal was two to three times wider than the smallest. Canal area significantly influenced the PGP at both levels ($P < 0.05$), however, the variation in PGP was only partially explained by canal area ($r^2 = 0.154$, 6 mm; $r^2 = 0.119$, 3 mm). The PGP at the 3 mm level was lower than at 6 mm ($P = 0.003$). The spreader-sequence technique achieved a higher PGP than the other two techniques ($P = 0.00002$). The control group had the lowest area of GP.

Conclusions Variations in root canal filling technique and canal area influenced the percentage of gutta-percha of laterally compacted root fillings. The percentage of gutta-percha was lower at the 3 mm level compared to the 6 mm level.

Keywords: lateral compaction, percentage of gutta-percha filled canal area.

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Introduction

Gutta-percha (GP) combined with a sealer are often used to fill root canals. GP is dimensionally stable (Wu *et al.* 2000a) whereas most sealers dissolve (Ørstavik 1983, Kazemi *et al.* 1993) with the potential for an increase in leakage along the root fillings over time (Kontakiotis *et al.* 1997). In general terms, GP compaction techniques are preferred because they maximize the volume of GP and result in a thin layer of sealer on the canal walls. Hence, the percentage of GP filled canal area (PGP) has been used as a measure of the quality of the root filling (Silver *et al.* 1999, Gound *et al.* 2001, Wu *et al.* 2001a, Jarrett *et al.* 2004).

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Cold lateral compaction (LC) is taught and practiced worldwide (Cailleteau & Mullaney 1997, Qualtrough *et al.* 1999, Dulaimi & Wali Al-Hashimi 2005) and it remains the technique of choice for many clinicians (Jarrett *et al.* 2004, Dulaimi & Wali Al-Hashimi 2005, Gulsahi *et al.* 2007). It also serves as the gold-standard against which new techniques are compared (Gordon *et al.* 2005, Xu *et al.* 2007).

Since lateral compaction was first described (Hall 1930), several modifications have been introduced in relation to the use of spreaders and accessory cones (Weine 1996, Gutmann & Witherspoon 2002). Hand and finger spreaders, 2%-tapered standard GP cones, and larger-tapered nonstandard GP cones are used currently (Gutmann & Witherspoon 2002). According to the literature the PGP achieved by LC varied from 43% (Kececi *et al.* 2005) to 100% (VanGheluwe & Wilcox 1996) depending on the tooth group (canal width), technique, the level where the root was sectioned, as well as other factors (Eguchi *et al.* 1985, Gencoglu *et al.* 2002).

To increase the PGP with LC, a spreader is forced in an apical direction to create space for an accessory cone. When the spreader cannot penetrate, it indicates that the apical portion is filled and that there is no space for further GP compaction. However, low PGP in the apical area after LC was previously reported (Eguchi *et al.* 1985, Gutmann *et al.* 2006). Unfortunately, attempts to increase PGP, through high forces transferred to the spreader (Schmidt *et al.* 2000), might increase the risk of root fractures (Meister *et al.* 1980, Wilcox *et al.* 1997).

Another concern when using LC is the possibility of premature coronal filling. Considering that all GP cones are wider coronally, the coronal root canal is likely to be filled earlier than the apical, especially if large-tapered nonstandard accessory cones are used. When premature coronal filling occurs, placement of GP cones apically is impossible (Wu *et al.* 2003a). To prevent premature coronal obturation and increase the PGP in the apical region, a sufficiently tapered root canal is required (Buchanan 2000). However, the optimum taper has not been defined. Additionally, in canals with wide apical regions (Wu *et al.* 2000b), achieving adequate root canal taper for LC, might be difficult.

A variation in cold lateral compaction is suggested (Dr Carlos Garcia Puente, Santa Fé, Argentina, personal communication) where a sequence of finger spreaders A-D (Dentsply Maillefer, Ballaigues, Switzerland), one after the other, is used to create space for the placement of a single accessory cone. The concept supporting this technique is that it enables a more effective movement and progressive deformation of GP, which may result in a better GP compaction. Following this approach a larger space following the use of the last spreader is expected which may enable the placement of a larger accessory cone, possibly resulting in a higher GP density. However, this technique has never been tested.

The aim of this study was to determine the effects of different lateral compaction techniques and the canal area on the percentage of GP within fillings at different levels of the root.

Materials and methods

Specimens' selection and preparation

Eighty caries-free maxillary and mandibular human canine teeth were used. Proximal radiographs confirmed the presence of a single straight root canal with 0.8 to1.0 mm internal diameter at 5 mm from the apex to ensure similar anatomic conditions for all groups (Wu *et al.* 2003a). After coronal access, the working length (WL) was determined 1 mm coronal to the apical foramen which was determined by inserting a size 15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) into the canal until the tip of the file was just visible.

The root canals were instrumented to WL with K-files sizes 20 to 50 and a step-back flaring technique at 1 mm increments using K-files sizes 60 to 100. This resulted in a taper of 0.1 mm mm^{-1}. After each file, the canals were irrigated with 2 mL of a 2% NaOCl solution. After instrumentation the canals were irrigated with 6 mL of 2% NaOCl for 1 min using passive ultrasonic irrigation with the intermittent flush technique (van der Sluis *et al.* 2007). Canals were dried with paper-points.

Groups division and root canal obturation

Samples were randomly distributed in four groups of 20 teeth each. The sealer (AH Plus, Dentsply DeTrey GmbH, Konstanz, Germany) was placed in the root canal using a bi-directional size 25 spiral filler (EDS, Hackensack, NJ, USA) three times, 5 s each, at a low rotation speed (840 rpm) to 1 mm short of WL. It was previously shown that in root canals in which sealer was delivered using a bi-directional spiral, more than 99% of the canal area was filled with both sealer and

GP (Wu *et al.* 2003b). As master cones were found to vary in size (Moule *et al.* 2002) a standard GP master cone (taper 0.02) size 45 (Henry Schein Inc., Mexico) was trimmed to size 50 to provide tugback at working length. This GP cone was coated with sealer and placed into the canal until WL. Subsequently, different procedures were followed for each group:

Group I: finger spreader C (D_1 0.3, taper 0.04) (Dentsply Maillefer, Ballaigues, Switzerland) and standard accessory cones size 25 were used (Wu *et al.* 2003a).

Group II: a hand spreader size D11 (D_1 0.5, taper 0.035) (RCSD116, Hu-friedy, Chicago, Ill, USA) and nonstandard accessory cones size medium-fine (D_1 0.08, taper 0.034) (Autofit Analytic Endodontics, Glendora, Ca, USA) were used (Gutmann & Witherspoon 2002).

Group III: Spreader A (D_1 0.2, taper 0.025) was introduced alongside the master cone until a maximum apical load of 2 kg was achieved and kept in position for 15 s. After removing spreader A, spreader B (D_1 0.25, taper 0.03) was introduced to the same length and maintained in position for 15 s. The same procedure was repeated for spreaders C and finally D (D_1 0.35, taper 0.06). In case spreader D did not reach the same length as C, the latter was re-introduced and selected as the final spreader. This was also the procedure when spreader C did not reach the same length as spreader B. A standard accessory cone was selected to fill the opened space according to the size of the final spreader: if D, GP cone size 30, if C, size 25, and in case of B, size 20.

Negative Control Group: no spreader was used. Standard size 25 GP cones were freely introduced in the root canal in one single movement until resistance was met.

For all the experimental groups, spreaders were introduced for the first time to 1 mm short to the WL and spreader compaction was carried out until 6 mm coronal of the starting point (Fig. 1). The samples were fixed on the plate of a digital scale and the force applied to each spreader penetration (2 Kg maximum) was controlled (Wu *et al.* 2003a). In the control group, as many accessory cones as possible were placed into canals until the same level (8 mm from the apex) had been reached (Fig. 1). Each accessory cone was coated with sealer. A heated plugger removed the coronal excess of GP with no further vertical compaction. Roots were kept for one week at 37 °C and 100% humidity to allow the sealers to set.

Roots sectioning and image capture and analysis

A low-speed saw under water cooling (Sagemicrotom 1600, Leitz, Wetzlar, Germany) sectioned the roots horizontally at 3 and 6 mm from the apex. Sections were photographed (×50) with a Photomacroscoop M400 microscope (Wild, Heerbrugg, Switzerland) and

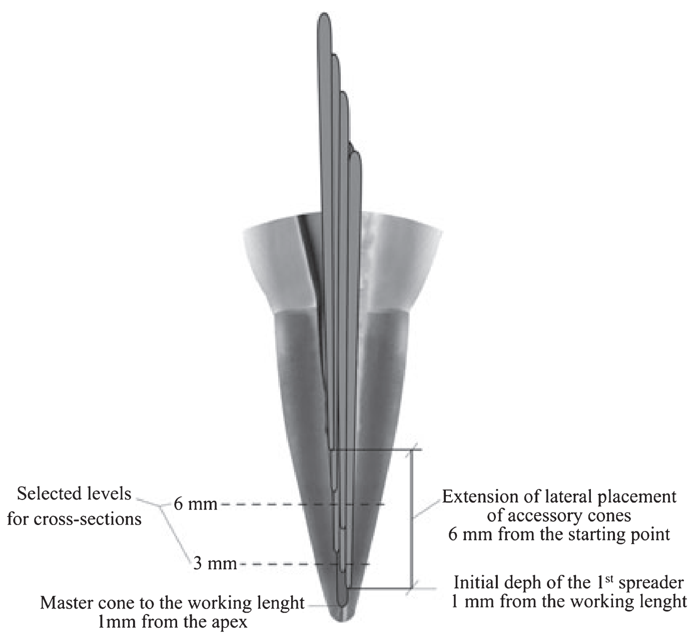

Figure 1 Schematic illustration for lateral placement of accessory gutta-percha cones and root-sectioning.

a digital camera and images saved in TIFF format. Using a KS 100 Imaging system 3.0 (Carl Zeiss Vision GmbH, Hallbergmoos, Germany) the area of the canal and GP were outlined and measured. The percentage of GP-filled canal area (PGP) was calculated at both sectioning levels. The relationship between canal area and PGP filling was analysed at both sectioning levels.

Statistical analysis

The results were analysed using a Multivariate analysis of variance with a Bonferroni *post-hoc* test for pairwise comparisons. PGP was the dependent variable, while technique and levels were fixed factors, and canal area, the covariate. A linear regression test was used to verify the amount of PGP variation that could be explained by canal area at both sectioning levels. The control group was not included in the statistical analysis since a spreader was not used and the inclusion would have influenced the comparison between LC groups. The level of significance was set at 0.05.

Results

The results for canal area, GP area, and PGP at levels 3 and 6 mm from the apex in each group are described in Table 1.

Multivariate analysis of variance demonstrated that filling technique ($P = 0.00002$), canal area ($P = 0.009$) and level ($P = 0.003$) significantly influenced the PGP.

There was no significant difference on the PGP displayed by groups I and II (Multivariate analysis, $P = 0.172$), whereas the PGP of group III was significantly higher than the PGP of groups I and II (Multivariate analysis, $P < 0.001$, Table 1).

At each level the largest canal was found to be two to three times wider than the smallest. The linear regression test demonstrated a significant inverse relation between the canal area and the PGP at both 3 mm ($P = 0.007$) and 6 mm ($P = 0.02$) from the apex, that is, the larger the canal area, the lower the PGP. However, the variation in the PGP is only partially explained by the canal area variation ($r^2 = 0.119$ at 3 mm, $r^2 = 0.154$ at 6 mm). The PGP at the 3 mm level was lower than at 6 mm (Multivariate analysis, $P = 0.003$).

The control group had the lowest GP density (Fig. 2).

Discussion

The present study investigated the effects of different filling techniques and canal area on the percentage of gutta-percha of laterally compacted root fillings. The groups were standardized to select canine teeth after proximal radiographs indicated canals with similar widths. In addition, the same instrumentation regimen was carried out for all specimens to ensure the canal shapes were similar.

At 5 mm from the apex of canines, the buccal/lingual canal diameter was found to be up to 1.68 mm (Wu *et al.* 2000b), indicating that many canals were originally larger than the largest instrument used. Although in this study all canals were instrumented to the same size (50, 0.10 taper), a wide range of canal area was observed (Table 1). At each level the largest

Table 1 The canal and gutta-percha areas, and the percentage of gutta-percha filled canal area (PGP). Total represents the average mean of both levels for the PGP at each group

Group	Average canal area (range) in mm^2	Average GP area (±SD) in mm^2	Mean of PGP (±SD) in %
I			
3 mm	0.54 (0.34–0.85)	0.40 (±0.12)	74.8 (±15.2)
6 mm	1.23 (0.87–1.7)	0.96 (±0.21)	78.8 (±8.3)
total			76.8 (±12.2)
II			
3 mm	0.48 (0.31–0.91)	0.34 (±0.12)	71.3 (±11.0)
6 mm	1.15 (0.73–1.94)	0.84 (±0.20)	74.7 (±10.1)
total			73.0 (±10.6)
III			
3 mm	0.42 (0.27–0.74)	0.36 (±0.15)	87.4 (±10.0)
6 mm	1.02 (0.61–2.11)	0.90 (±0.45)	89.2 (±4.0)
total			88.3 (±7.6)
Control			
3 mm	0.53 (0.36–0.79)	0.33 (±0.06)	64.1 (±7.1)
6 mm	0.96 (0.72–1.36)	0.59 (±0.10)	61.9 (±4.5)
total			62.6 (±6.3)

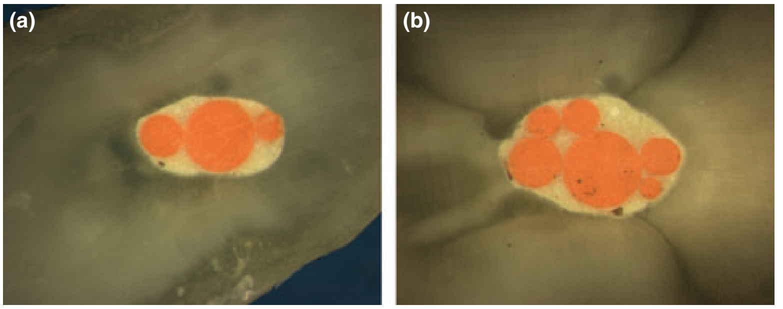

Figure 2 Two cross-sections of a specimen from the control group where a spreader was not used: 3 mm (a) and 6 mm (b) from the apex (×50 magnification).

canal was two to three-fold wider than the smallest, with the canal area varying from 0.27 to 0.91 mm^2 at the 3 mm level and from 0.61 to 2.11 mm^2 at the 6 mm level (Table 1). A great variability in canal area in root canals instrumented to the same size was previously observed (Wu *et al.* 2002a, De-Deus *et al.* 2006), and reported to influence the PGP of warm compacted root fillings (Wu *et al.* 2002a).

Despite the great differences in canal width observed between the largest and smallest canals, it is impossible to clinically determine which canal is large. It has been found that the first file that binds does not measure the apical diameter (Wu *et al.* 2002b). In the originally wide apical canals, the files used were indeed smaller than the canal, resulting in a taper smaller than the expected 0.10. As the coronal root canal was flared to size 100, it might be that the larger the discrepancy between the wide canal diameter and the small instrument the smaller the taper produced by the instrumentation. In those cases, premature coronal filling might occur and the PGP at both 3 and 6 mm was reduced (Buchanan 2000). The influence of canal area on the PGP was more pronounced at the 3 mm level ($P = 0.007$) than at the 6 mm level ($P = 0.02$), explaining why the apical PGP was lower than at the middle level ($P = 0.003$). Since the canal size cannot be clinically determined, the desired root canal taper would not be achieved; the PGP of LC fillings is, therefore, unpredictable.

One may argue that there is no relationship between canal area and PGP, due to the low r^2 value obtained in the regression test. However, the null hypothesis of no relationship between PGP and canal area is rejected since the *P*-value was below 0.05 at both levels. The r^2 represents the amount of the variation in PGP (in percentage) that could be explained by the variation in canal size. Since the r^2 is not that high, it is concluded that canal area variation is not the only factor influencing the PGP (Landau & Everitt 2004). It is hypothesized that irregularly shaped root canals might also play a role in the PGP, since areas beyond the reach of the instruments are poorly filled with GP using LC (Wu *et al.* 2001b). Nevertheless, the root canal perimeter was not measured in the present study. According to the finds of the present study, the variation in PGP is significantly influenced by the canal area variation, however others factors might also be influencing this parameter.

Variations in the LC technique also influenced the PGP considering that group III had significantly higher PGP than the other two groups (Table 1) where commonly used techniques (Gutmann & Witherspoon 2002, Wu *et al.* 2003a) were performed. Clearly, the use of a sequence of spreaders prior to the accessory cone placement in group III enabled better GP compaction (Fig. 3). The PGP achieved apically (Table 1, Fig. 3) was comparable to that achieved by the warm GP technique using System B (Silver *et al.* 1999,

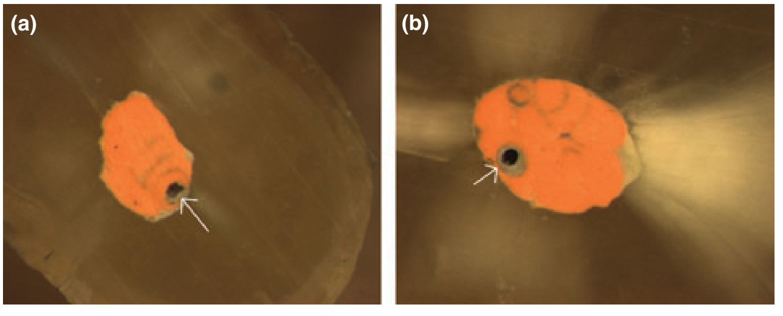

Figure 3 Two cross-sections of group III where a sequence of finger spreaders A–D was used prior to each accessory cone placement at levels 3 mm (a) and 6 mm (b) from the apex (×50 magnification). Arrows demonstrate large, round, unfilled voids.

Gencoglu 2003). However, it is a time-consuming technique because at least 1 min of compaction is required before an accessory cone can be placed.

In group II, larger-tapered nonstandard GP cones were used. Due to the larger coronal density, those cones could severely interfere with each other at the coronal opening resulting in premature coronal filling. The average apical PGP was 16.1% lower for group II than group III (Table 1), indicating that due to premature coronal filling, less GP density could be achieved in the apical root canal when larger-tapered nonstandard accessory cones are used. When premature coronal filling occurs it became questionable whether high forces should be transferred to the spreader in order to increase the apical GP density. Excessive and uncontrolled forces transferred to spreader might cause root fractures (Meister *et al.* 1980) or influence the PGP. It was for those reasons that the spreader load used in the present study was limited to a maximum of 2 Kg.

Furthermore, the size and taper of accessory cones chosen in all groups was always smaller than the last spreader used (Gound *et al.* 2001) to enable GP placement to the entire extension of the spreader track. However, big round-shape unfilled voids, resembling unfilled spreader tracks were frequently observed (Fig. 3) as in previous reports (Brayton *et al.* 1973, Eguchi *et al.* 1985, Budd *et al.* 1991, Jarrett *et al.* 2004). An indication that the big round-shape voids observed in LC groups were, in fact, spreader tracks, is that none of the samples were presented with big round-shape unfilled voids in the control group where no spreader was used. It may be that all three LC techniques left spreader tracks. Size variation within accessory cones of the same brand (Moule *et al.* 2002) and lack of standardization between spreader size and accessory cones (Hartwell *et al.* 1991) might explain the observation of unfilled spreader-tracks.

The rationale of the lateral compaction technique is to increase the GP ratio to sealer in the root canal aiming to potentially decrease the gaps that might occur due to sealer contraction or dissolution, especially in the apical region. According to the findings of the present study, canal anatomy potentially interferes with the PGP of LC fillings. Gordon *et al.* (2005) compared the PGP achieved by LC to a technique where a single matched cone was used. Simulated resin root canal and mesio-buccal roots of extracted mandibular molars were instrumented to the same size following the same instrumentation regimen. In extracted teeth the PGP dropped approximately 10% in both techniques at the 1.5 mm level. Variations in canal anatomy in extracted teeth (not present in simulated canals) might be the reason for such a variation in the PGP of root fillings (Gordon *et al.* 2005).

Since several factors might influence the result of a root canal filling, a multivariate analysis of variance was used in the present study to ensure the simultaneous investigation of various potential factors influencing the PGP. As the covariate (canal area) was found to influence the PGP of LC fillings, a linear regression test was performed to verify the degree of PGP variation that could be explained by canal area variation. According to the results of the present study, variations in the root canal filling technique, canal area and the level significantly influenced the PGP of laterally compacted root fillings. The variations in PGP observed in the present study are partially explained by the changes in canal area.

Conclusions

The variation in the PGP achieved by LC at both 3 and 6 mm levels was partially explained by canal area variation. This influence was significant at both levels. A variation in cold lateral compaction technique with use of a sequence of spreaders prior to the accessory cone placement enabled a better GP compaction than other commonly used techniques.

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