# A comparison of spreader penetration depth and load required during lateral condensation in teeth prepared using various root canal preparation techniques

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## Abstract

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**Aim** To compare the influence of various root canal preparation techniques on spreader penetration depth and load required during lateral condensation with gutta-percha and sealer.

**Methodology** Eighty extracted human teeth with single and straight canals were used. Twenty teeth were instrumented using one of four root canal preparation techniques. The four preparation techniques were: step-back technique without Gates-Glidden drills, step-back technique with Gates-Glidden drills, crown-down pressureless technique and hybrid technique (step-down/ step-back). After root canal preparation had been completed a simulated periodontal ligament was fabricated from a uniform layer of silicone impression material. The roots were then mounted in an acrylic resin to simulate the physical condition found in tooth socket. A standardized stainless steel hand spreader of the same size as the master apical file was mounted in an Instron testing machine and lateral compaction with gutta-percha and sealer was performed. The load value was recorded from the Instron testing machine. The spreader penetration depths were measured with an endodontic ruler. The data obtained were analysed statistically using ANOVA and Student's *t*-tests.

**Results** No significant difference in initial spreader load needed to condense the master cone was found amongst the four canal preparation techniques ($P > 0.05$). The step-back technique with Gates-Glidden drills and the hybrid technique demonstrated the least difference between the initial spreader penetration and the working length (mean 1.925 and 2.25 mm, respectively). The step-back technique without Gates-Glidden drills and the crown-down pressureless technique had the greatest difference between initial spreader penetration and the working length (mean 4.425 and 4.75 mm, respectively).

**Conclusion** The flare created by canal preparation affected spreader penetration depth, but had no effect on the spreader load.

**Keywords:** endodontic spreader loads, lateral condensation, root canal preparation techniques.

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## Introduction

The major objective of intracanal treatment procedures is to remove the infected contents of the canal and facilitate filling (Weine 1996).

Lateral compaction of cold gutta-percha with sealer is taught and practiced throughout the world and is the technique of choice for many clinicians. It is relatively simple and rapid to carry out and is the standard obturation method against which many new techniques are compared (Dummer 1997).

Allison *et al.* (1979) reported that root canals prepared with a flared shape permitted a spreader tip to be inserted to within 1 mm of the prepared

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length resulted in a considerably superior apical seal compared with root canals in which the distance between the spreader tip and prepared length was greater.

During lateral compaction with gutta-percha and sealer, the clinician may use substantial condensation forces to achieve deep initial spreader insertion (Schmidt *et al.* 2000). Meister *et al.* (1980) reported that 85% of vertical root fractures were caused by excessive force used during the lateral compaction procedures.

The aim of this study was to compare initial spreader penetration depth and the load required to condense the master cone during lateral compaction of gutta-percha and sealer in straight canals, prepared using four different canal shaping techniques.

## Materials and methods

### Specimen preparation

Eighty mandibular premolars with single straight root canals and completely formed apices that had been stored in normal saline were selected for instrumentation. Using a diamond disc (Komet, Cebr Brasseler GmbH & Co. KG, Lemgo, Germany) in a straight hand piece with water coolant, the crowns of the teeth were sectioned perpendicular to the long axis of the root at a point approximately 3 mm coronal to the cemento-enamel junction (CEJ) in order to facilitate straight line access for canal instrumentation and filling procedures (Pitts *et al.* 1983).

### Canal instrumentation

*Group I*

Twenty teeth were instrumented with a step-back technique (Weine 1996) without using Gates-Glidden drills. After determining the working length, apical preparation continued with circumferential filing of the canal walls and continued until three full sizes greater than the first file to bind at the working length. Instrumentation was completed using stainless steel K-files (Dentsply Maillefer, Ballaigues, Switzerland). The size of the completed apical preparation ranged from 35 to 40. Flaring of the remaining canal by stepping back to size 60 or 70 allowed an endodontic spreader (Union Broach, New York, NY, USA) of the same size as the apical preparation, to approach to within 1 mm of the working length without binding.

*Group II*

Twenty teeth were instrumented by the step-back technique (West *et al.* 1994, Walton 1996, Weine 1996) with the use of Gates-Glidden drills (Dentsply Maillefer). After determination of the working length using a size 10 K-file, canals were enlarged to size 35 using a filing action prior to using Gates-Glidden drills. To flare the coronal and middle third of the canal a size 2 Gates-Glidden drill in a contra-angle handpiece was inserted several millimetres into the canal with light force, and then followed by sizes 3 and 4. The procedure was accompanied by copious irrigation with 2.5% NaOCl. Apical preparation followed with the final master apical file ranging between 35 and 40. Flaring of the remainder of the canal was completed with peripheral filing to size 60 or 70.

*Group III*

Twenty teeth were instrumented with the crown-down pressureless technique according to the Oregon Health Sciences University technique manual (Marshall & Pappin 1987). Canal preparation continued by placing a straight size 35 file to the point of first resistance without apical force. Flaring of the coronal portion of the canal was completed with Gates-Glidden drills from larger to smaller using sizes 4, 3 and 2 with copious irrigation (2.5% NaOCl) between each instrument. A provisional working length was established 3 mm from the full root length. K-files were then used with a reciprocal reaming action (rotating the file back and forth in a 90°–180° arc) and in crown-down sequence from larger to smaller to reach provisional working length. The true working length was determined using a size 10 K-file placed into the root canal until it was visible at the apical foramen and then 1 mm subtracted from this length. A file larger than the largest used in the series to establish provisional working length was selected. Sequential files used with reciprocal reaming in a crown-down sequence with recapitulation to true working length with size 15 K-files and irrigation. These sequences continued until the apical preparation was enlarged three sizes larger than the first file that bound at true working length. The size of apical preparation was 40 for all 20 specimens.

*Group IV*

Twenty teeth were instrumented with a hybrid step-down/step-back technique according to Goerig *et al.* (1982). The root canals were copiously irrigated, followed by sequential introduction of Hedström files 15, 20 and 25 into the canal to a level approximately at the junction of the middle and apical thirds of root. The canal was irrigated followed by the introduction of a size 2 Gates-Glidden drill 8–10 mm into the canal followed by sizes 3 and 4. Prior to apical preparation, the working length of the root canal was established with a size 10 K-file passed into the root canal until it was visible at the apical foramen and 1 mm subtracted from this length. The apical portion was shaped with size 15 and 20 K-files to the apical foramen and the apical stop established using a size 25 K-file 1 mm short of the apical foramen. Files were used in a 180° rotation and withdrawal reaming action. Sequential files were used with a reaming action whilst stepping back to size 60. A K-file sized 25 was used to recapitulate to the apical stop during the step-back procedure. The apical stop was further enlarged to a size 35 according to Goerig *et al.* (1982).

### Preparation of test assembly

After preparation the canals were dried with paper points (Roeko, Langenau, Germany). The root of each specimen was wrapped with one thickness of lead foil backing from an X-ray film to the level of the CEJ and lubricated with vaseline. An acrylic resin (Medicus Cold Cure, DMP Ltd, EU shipped by Spectra Ltd, Moscow, Russia) mixed according to the manufacturer's instructions was poured into brass cylindrical moulds lubricated with vaseline. The root of each specimen was then embedded in a fresh mix of acrylic resin to the level of the CEJ. A surveyor was used to position the long axis of the tooth parallel to that of the brass mould in order to provide straight-line vertical penetration of the spreader during testing. After the acrylic resin had set, the root was removed along with the lead foil. Silicone impression material (DoriDent, Dr Hirschberg GmbH, Vienna, Austria) was mixed according to the manufacturer's instructions and painted onto the surface of the root with a wax knife. The root was repositioned in its created acrylic resin socket and excess silicone impression material removed. This created an artificial socket which simulated the periodontal membrane found in a tooth socket (Pitts *et al.* 1983).

### Canal filling and test procedure

After the root canals had been dried with paper points (Roeko, Langenau, Germany), Dorifill root canal sealer (DoriDent) was mixed manually according to the manufacturer's recommendations. A reamer one size smaller than the MAF was selected, a rubber stopper positioned at the working length and a small amount of sealer picked up with its tip. The reamer was placed to the correct working length in the canal and rotated counterclockwise to spin the sealer into the canal. A master gutta-percha cone (DiaDent Group International, Chongiu City, Korea) corresponding to the MAF was coated with sealer and placed in the canal to the full working length.

The Instron testing machine (Zwick 1454, Zwick GmbH & Co. KG, Ulm, Germany) was set to apply a load at a speed of 5 cm min$^{-1}$ (Pitts *et al.* 1983). The spreader was a standardized stainless steel hand spreader of the same size as the master apical file. The spreader was mounted in the Instron testing machine parallel to the long axis of the acrylic block. The Instron device then inserted the spreader into the canal in order to condense the master gutta-percha cone. When the spreader stopped entering into the canal, it was maintained at this position for 30 s (Dang & Walton 1989) and the load value recorded.

After 30 s, the jig of the Instron machine was released and the spreader removed from the root canal with a back and forth motion. To control rebound of gutta-percha, no more than 5 s was allowed to elapse after removal of the spreader before placing an accessory cone (Jerome *et al.* 1988). Spreader penetration was recorded according to the position of the rubber stopper. In this manner, lateral compaction of gutta-percha and sealer was performed until the spreader could not enter more than 3–5 mm into the canal.

## Results

The summary of the mean values and standard deviation (SD) with the maximum (Max) and the minimum (Min) values of initial spreader load, in kilogram needed to condense the master cone for each canal preparation technique are presented in Table 1.

**Table 1** Statistical summary

| | Group I L1 | Group II L2 | Group III L3 | Group IV L4 |
|---|---|---|---|---|
| *n* | 20 | 20 | 20 | 20 |
| Minimum | 0.9 | 1.0 | 1.1 | 1.0 |
| Maximum | 2.9 | 3.0 | 1.8 | 1.8 |
| Sum | 28.2 | 32.3 | 26.2 | 28.9 |
| Mean | 1.41 | 1.615 | 1.31 | 1.445 |
| SD | 0.5149 | 0.577 | 0.2049 | 0.2625 |

L, initial spreader load needed to condense the master cone (kg).

**Table 2** The mean differences between initial penetration depth of the spreader and the working length

| | Group I $In_1$ (mm) | Group II $In_2$ (mm) | Group III $In_3$ (mm) | Group IV $In_4$ (mm) |
|---|---|---|---|---|
| *n* | 20 | 20 | 20 | 20 |
| Minimum | 1.5 | 1.0 | 2.5 | 1.0 |
| Maximum | 7.5 | 3.5 | 7.0 | 3.5 |
| Sum | 88.5 | 38.5 | 95.0 | 45.0 |
| Mean | 4.425 | 1.925 | 4.75 | 2.25 |
| SD | 1.5917 | 0.6935 | 1.2618 | 0.7695 |

In, the differences between the initial penetration depth of spreader and the working length (mm).

The summary of the mean and SD values of the differences between the initial penetration depth in millimetres of spreader and the working length, for each canal preparation technique are presented in Table 2.

From Table 1 it was clear that canals shaped by the crown-down pressureless technique had the lowest mean spreader load (1.31 kg) followed by the step-back technique without Gates-Glidden drills (1.41 kg), then the hybrid technique (1.445 kg). The greatest mean value of spreader load was associated with the step-back technique with Gates-Glidden drills (1.615 kg).

From Table 2 it was obvious that the step-back technique with Gates-Glidden had the least difference between the depth of spreader penetration and the working length (1.925 mm), followed by hybrid technique (2.25 mm), then the step-back technique without Gates-Glidden drills. The greatest difference between the depth of penetration of the spreader and the working length was associated with the crown-down pressureless technique (4.75 mm).

Statistical analysis of the data using analysis of variance (ANOVA) was performed. The results showed that there was no significant difference ($P > 0.05$) between the four root canal preparation techniques in initial spreader load required to condense the master cone.

However, analysis of variance (ANOVA) between the four root canal preparation techniques in the means of the difference between the initial penetration depth of spreader and the working length showed highly significant differences ($P \leq 0.01$).

The Student's *t*-test was used to evaluate the significance of the difference between each pair of groups. Table 3 outlines the results of the Student's *t*-test concerning spreader load required to condense the master gutta-percha cone. Only the step-back technique with Gates-Glidden drills had a significant difference ($P \leq 0.05$) compared with the crown-down pressureless technique.

**Table 3** Student's *t*-test results comparing all pairs of groups concerning spreader load required to condense the master cone

| Comparison groups | Df | *T* | *P*-values | C.S. |
|---|---|---|---|---|
| $L_1$ versus $L_2$ | 19 | 1.331 | >0.05 | NS |
| $L_1$ versus $L_3$ | 19 | 0.917 | >0.05 | NS |
| $L_1$ versus $L_4$ | 19 | 0.240 | >0.05 | NS |
| $L_2$ versus $L_3$ | 19 | 2.409 | ≤0.05 | * |
| $L_2$ versus $L_4$ | 19 | 1.166 | >0.05 | NS |
| $L_3$ versus $L_4$ | 19 | 1.897 | >0.05 | NS |

NS, not significant; L, mean of initial spreader load.
*Significant.

**Table 4** Student's *t*-test results comparing all pairs of groups regarding the differences between the initial spreader penetration and the working length

| Comparison groups | Df | *T* | *P*-values | C.S. |
|---|---|---|---|---|
| $In_1$ versus $In_2$ | 19 | 6.483 | ≤0.001 | *** |
| $In_1$ versus $In_3$ | 19 | 0.768 | >0.05 | N.S. |
| $In_1$ versus $In_4$ | 19 | 4.992 | ≤0.001 | *** |
| $In_2$ versus $In_3$ | 19 | 8.534 | ≤0.01 | ** |
| $In_2$ versus $In_4$ | 19 | 1.317 | >0.05 | N.S. |
| $In_3$ versus $In_4$ | 19 | 7.147 | ≤0.01 | ** |

NS, not significant; In, mean of differences between the initial spreader penetration depth and the working length.
**Highly significant.
***Very highly significant.

Table 4 outline the results of the analysis for the differences between the initial penetration depth of the spreader and the working length.

A highly significant difference ($P \leq 0.01$) was found between the step-back with Gates-Glidden drills compared with the crown-down pressureless technique, and the crown-down pressureless technique compared with the hybrid technique.

## Discussion

Lateral condensation of gutta-percha is by far the most popular technique for canal filling, both in practice and as taught in most dental schools (Walton & Johnson 1996). The canal preparation technique is an important factor that affects the depth of initial spreader penetration, and as a consequence, affects the quality of the apical seal (Allison *et al.* 1979, 1981). However, increased spreader load during filling may cause immediate vertical root fracture that has been reported to be affected by spreader type and more likely to occur with the D-11-T spreader (Holcomb *et al.* 1987, Lindauer *et al.* 1989).

Hatton *et al.* (1988) suggested investigating and developing a canal preparation technique that would allow the spreader to approach to within 1–2 mm of the apex with minimal force. This canal preparation technique would aid in the creation of a good apical seal with less likelihood of vertical root fracture.

In the present study, approximation of the clinical situation was carried out by simulation of the PDL using silicone impression material and spreader removal in a back and forth motion. The gutta-percha was under compression for 30 s. Dang & Walton (1989) and Sakkal *et al.* (1991) recommended a compression time from 10 to 60 s to allow the gutta-percha to deform before spreader removal.

In the present study, the range of spreader load during initial penetration was (0.9–3 kg), which agrees with the finding of Harvey *et al.* (1981) who reported that maximum forces used by endodontists during root filling ranged from 1–3 kg. This range has been considered as safe and that would not produce vertical root fracture (Lindauer *et al.* 1989, Saw & Messer 1995, Blum *et al.* 1997a,b).

Holcomb *et al.* (1987) stated that a spreader load of 1.5 kg could cause vertical root fracture. These findings may be attributed to the experimental procedure which was performed on mandibular central incisors and the penetration depth of the spreader was fixed for each insertion of the spreader into the root canal.

Lindauer *et al.* (1989) stated that the possibility of vertical root fracture is increased when a D-11-T spreader was used due to its greater taper and stiff metal that could withstand a 7 kg load without distortion. The results of the present study demonstrated that there were no statistically significant differences between the four canal preparation techniques ($P > 0.05$) regarding the initial spreader load used to condense the master gutta-percha cone; the same results were found by Hatton *et al.* (1988).

On the other hand, the present study has indicated that canal preparation technique had a significant effect on the differences between initial penetration depth of the spreader and the working length. There were statistically highly significant differences between the four canal preparation techniques ($P \leq 0.01$) regarding the mean of the differences between the initial penetration depth of spreader and the working length; this implies that canal preparation technique may be the main factor which affects initial penetration of the spreader (Table 2). When flaring of a prepared canal does not allow deep insertion of the spreader, increasing the spreader load may increase the possibility of vertical root fracture.

The step-back preparation technique with Gates-Glidden drills had the least differences between the initial penetration of the spreader and the working length (mean 1.925 mm) (Table 2). This may be related to the combination of the flaring of Gates-Glidden drills and the circumferential filing. It was clear that the flaring in this technique provided sufficient space for deeper insertion of the spreader.

The step-back preparation technique with Gates-Glidden drills had the mean value of spreader load with initial insertion equal to 1.615 kg (Table 1), which is not significantly different when compared with the other canal preparation techniques studied ($P > 0.05$) except for the crown-down pressureless technique that scored 1.31 kg ($P \leq 0.05$) (Table 3). This can be explained by close approximation of the canal walls in the apical third with the presence of the gutta-percha master cone, offering resistance to spreader insertion.

The use of Gates-Glidden drills with a step-back preparation technique caused highly significant differences between the initial spreader insertion and the working length ($P \leq 0.001$) compared with the step-back preparation technique without the use of Gates-Glidden burs (Table 4). This may mean that circumferential filing with stepping back was not sufficient to establish an adequate amount of flare to permit penetration of the spreader to within 1–2 mm of the full working length.

The hybrid technique (step-down/step-back) showed no statistically significant differences from the step-back technique with Gates-Glidden drills ($P > 0.05$) between the initial penetration of the spreader and the working length (Table 4). The step-back technique with Gates-Glidden drills had the lowest mean (1.925 mm) of the difference between initial penetration depth and the working length compared with the hybrid technique (2.25 mm) (Table 2). This can be related to the combination of flaring with Gates-Glidden in the coronal third, with Hedström file in the middle third and with the stepping back file in the apical third.

It was surprising to find that the crown-down pressureless technique had the greater mean difference between the initial penetration of the spreader (4.75 mm) and the working length (Table 2), which may be related to limiting the use of Gates-Glidden drills to the coronal level with the remainder of the canal being prepared with files using reciprocal reaming with minimal force and minimal removal of tooth structure.

 

## Conclusions

In the present study, a standardized stainless steel hand spreader was used in the lateral condensation obturation technique. The size of the spreader was equal to the size of the apical preparation. Into these conditions, the following conclusions can be drawn:

**1.** Initial spreader loads required to condense master cones in teeth prepared using the four canal preparation techniques tested, were not statistically different.

**2.** The step-back canal preparation technique with Gates-Glidden drills was associated with the least difference between initial spreader penetration and the working length and was not significantly different to the hybrid technique.

**3.** The crown-down pressureless canal preparation technique was associated with the greatest difference between the initial spreader penetration and the working length. However, it was not significantly different when compared with the step-back without the use of Gates-Glidden burs.

**4.** The spreader load of 1–3 kg may be sufficient to condense the master gutta-percha cone during lateral compaction.

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