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Original Article

Fracture resistance of overtly flaring root canals filled with resin-based obturation material

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ABSTRACT

Background: Reinforcement of root canals obturated with Resilon was reported by several investigators, but no studies reported the reinforcement of overtly flared root canals obturated with Resilon material. The aim of this study was to investigate the fracture resistance of overtly flared root canals filled with Resilon as compared to similar root canals filled with gutta-percha (GP).
Materials and Methods: Sixty single-rooted premolars were divided randomly into six groups. Group 1 served as control group. The control group was sub-divided into two groups, a negative group and a positive group. The negative group consisted of root canals that were only cleaned from residual pulpal tissues, however, the positive group had prepared and overtly flared root canals without obturation. Groups 2 and 4 were shaped using 0.04 taper rotary files, while groups 3 and 5 were shaped using 0.06 taper rotary files. Before obturation, the last four groups were further flared coronally with a reverse cone diamond bur. Groups 2 and 3 were obturated with GP and a resin-based sealer, while groups 4 and 5 were obturated with Resilon and Epiphany self-etching primer and Epiphany sealer. Roots were then fixed into a universal testing machine and vertically loaded until fracture. SPSS software (Release 9.0 for Windows, SPSS, Chicago, USA) was used to perform the statistical analysis.
Results: Fracture resistance measurements showed that there were differences in resistance to fracture among the experimental groups (ANOVA, $P < 0.0001$). Mean values of the loading force applied to the negative control group were the highest at 1.81 KN, whereas the mean values for the Resilon groups (Groups 4 and 5) at 1.13 KN and 1.54 KN were found to be higher than the GP groups (Groups 2 and 3) at 0.45 KN and 0.88 KN, respectively. Tukey's *post hoc* test showed that there was no statistical difference between the mean values of the negative control group and Group 5 ($P = 0.69$).
Conclusion: Obturation of overtly flared roots with Resilon material increased the resistance of these teeth to vertical root fracture.

Key Words: Epiphany, flared canals, gutta-percha, Resilon, root canal obturation

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INTRODUCTION

Root canal therapy aims to remove pathologic pulp, disinfect and shape the contaminated root canal system; and obturate three-dimensionally to prevent re-infection.[1-4] Although obturation is performed according to the highest clinical standards, to obtain an impervious seal is difficult. Different endodontic filling materials and technologies have been introduced to improve the apical seal.[4,5] The most popular is the combination of a zinc oxide-eugenol sealer with gutta-percha (GP) filling material. The use of sealers along with well-adapted GP gives the optimum chance of success.[1,6] However, endodontic therapy may also weaken the tooth. Factors such as trauma, over-preparation of canals cervically, removal of previously placed posts, previous endodontic treatment, and internal resorption[7] may lead to

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thinner and weaker canal walls, increasing the risk of vertical root fracture[8] and ultimate extraction of the tooth. Consequently, filling such radicular defects with restorative materials, such as glass-ionomer cement, phosphate glass-polycaprolactone-based composite and composite resin has been suggested to reinforce weakened roots.[9]

In order for the adhesive dental material to reinforce the tooth structure, it must bond to dentin through its hydrophilicity and ability to infiltrate dentine surface. The bonding concept of GP is hampered by the lack of a chemical union between the polyisoprene component of GP and resin-based resin sealers.[10] In 2004, Resilon was introduced under the name RealSeal (Pentron Clinical Technologies, Wallingford, CT) containing Resilon and a resin-based sealer. Resilon is a thermoplastic synthetic polymer-based root canal filling material. Based on polymers of polyester, Resilon contains bioactive glasses and radiopaque fillers. It performs in a similar way to GP, has the same handling properties, and for retreatment purposes may be heat-softened or dissolved with solvents such as chloroform. The RealSeal sealer is a dual curable dentin resin composite sealer and may be used in conjunction with Resilon points. Recent studies have compared the fracture forces of roots obturated with Resilon and GP[11] but no studies yet have compared the fracture force of weakened roots obturated with these materials.

The aim of this *in-vitro* study was to evaluate the effect of Resilon and GP obturating materials on vertical forces at fracture of overtly flared root canals. Additionally, this study analyzed teeth which were prepared either using 0.04 taper or 0.06 taper rotary instruments before additional coronal flaring and obturation. The null hypothesis was that there are no differences in the vertical forces of fracture between materials or taper preparation.

MATERIALS AND METHODS

Teeth collection and sample selection

Sixty sound extracted human single-rooted mandibular premolars were used. Immediately after extraction, the teeth were stored at room temperature in hermetically-sealed vials containing physiological saline. The teeth were examined under digital stereomicroscope (Motic Digital Microscope, Micro-Optic Industrial Group Co. LTD, France) to rule out any pre-existing root fractures. The premolars were sectioned at the cemento-enamel junction to remove the crowns using high-speed hand piece and diamond disc under water cooling. Root samples had the same curvature (0-5°) using Schneider technique and apical foramen equals to file size 15 in diameter. Preoperative periapical radiographs were taken to ensure that root samples had normal canal shape and adequate thickness of dentinal walls. The samples were randomly divided into six groups. Each group consisted of 10 samples (n = 10). Each sample was marked by a unique identification number.

Sample preparation

The working length of all the root canals was established at 15 mm using size 15 K Flex file (DENTSPLY Maillefer, Tulsa, OK). The working length was then set at 1 mm shorter than the apical foramen. In Group 1 (negative and positive control groups), the root canals of the negative control group (10 samples) were cleaned from pulpal residuals, but neither prepared nor obturated, while the remaining other groups were cleaned and shaped using Profile rotary instruments. In the positive control group (10 samples) the samples were instrumented and overtly flared without obturation. In groups 2 and 4 (20 root samples) were instrumented with NiTiProFile 0.04 (DENTSPLY Maillefer) tapered rotary files with crown-down pressure-less technique to size 35 master apical file. Similarly, the canals in groups 3 and 5 (20 root samples) were instrumented with NiTiProFile 0.06 tapered rotary files. The canals were irrigated during instrumentation with 1% sodium hypochlorite (NaOCL) and then rinsed with 5 ml of 17% ethylene-diamine-tetra-acetic acid (EDTA) to remove the smear layer, and followed by 5 ml of distilled water to remove the residue of NaOCL and EDTA. The canals were enlarged using Gates Glidden drill size 6 for 10 mm of the working length and then the cervical 5 mm was flared using a reverse cone diamond bur size 023HP [Figures 1a and b]. After total instrumentation the root samples were irrigated with distilled water. Instrumentation of root canals was standard throughout the study and completed by one investigator.

Obturation of samples

For groups 2 (ProFile 0.04) and 3 (ProFile 0.06) (n = 10 each) root canals were obturated with tapered GP using lateral condensation technique with master cone size 35 coated with the resin-based root canal sealer ADSEAL (Meta Biomed Co., LTD, Korea). The sealer was mixed according to the manufacturer's instructions and placed into the canals with a lentulo spiral (DENTSPLY Caulk, Milford, DE). Tapered GP master cones were placed and condensed at the appropriate working lengths (15 mm). Then accessory cones were placed and condensed using a finger spreader (Miltex, Inc., York, PA). The excess GP was removed with a hot instrument and condensed vertically with a plugger to the level of the canal orifice. Root canals in Group 4 (ProFile 0.04 taper, n = 10) and Group 5 (ProFile 0.06 taper, n = 10) were obturated with Resilon, Epiphany self-etching primer and Epiphany sealer (Pentron Clinical Technologies LLC). The primer was inserted into the root canals and the excess was removed with dry paper points (DENTSPLY Maillefer). Epiphany sealer was mixed according to the manufacturer's instructions and inserted into the root canals with a lentulo spiral. Resilon master cones, size 35, with appropriate taper (according to the ProFile taper used) were placed and condensed at the appropriate working length (15 mm). The accessory cones were then dipped in the Epiphany sealer and condensed using lateral condensation with a finger spreader. Excess Resilon cones were removed with a hot instrument and condensed vertically with a plugger to the level of the canal orifice.

Postoperative periapical radiographs of the roots samples were taken to ensure that the canals were completely obturated without any voids. All the samples were stored in distilled water for two weeks to allow complete setting of the sealer. After two weeks the root samples were mounted in acrylic resin blocks of 30 mm length and 35 mm diameter to avoid slipping of the sample during force-loading measurements. The apical part of the samples was embedded in acrylic resin blocks leaving 2 mm of the cervical part un-embedded. A pendulum scale was used to ensure vertical alignment of the long axis of the samples during acrylic resin polymerization.

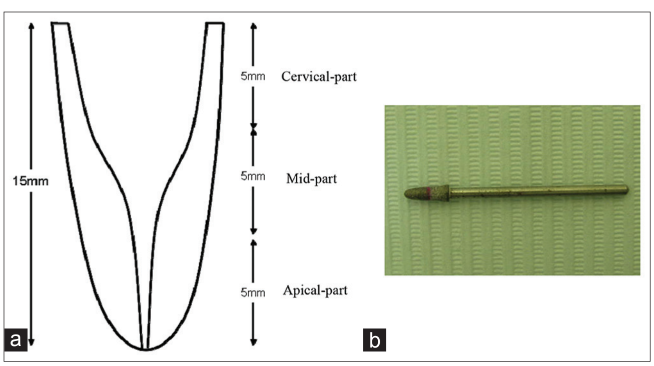

Figure 1: (a) Schematic diagram shows the steps of flaring a root canal, apical part (5 mm of the working length) prepared with NiTiProFile 0.04 or 0.06, mid and cervical parts (10 mm of the working length) enlarged using drill size 6. (b) A reverse cone diamond bur was then used to flare the cervical 5 mm of root canal

Sample holder

A special sample holder was fabricated from stainless steel. The sample holder consists of two cylindrical screw type bars mounted on the Universal testing machine. The upper bar ends with small ball (3 mm in diameter) directed precisely over the canal orifice of root sample, which imbedded in acrylic resin block seated on the lower bar seat. The sample holder was designed to standardize measurements, to protect acrylic resin blocks from tilting during measurements and to provide good visibility of the sample throughout the measurements.

Force-loading measurements

The measurements were carried out at room temperature using a computer-controlled, Universal Testing Machine (DARTEC, USA Model Company). The testing machine employs workshop 96, tool kit 96 and data manager software to analyze the measured data and plot the graphs. Acrylic resin blocks were grasped by the lower bar of the sample holder and the ball of the upper bar was directed precisely over the canal orifice. A continuous load was applied along the long axis of the root at cross-head speed of 1.0 mm/min until a fracture sound was indicated by the testing machine [Figure 2]. Then the loading force was recorded and analyzed in Kilo Newton (KN) by the testing machine.

Statistical analysis

SPSS software (Release 9.0 for Windows, SPSS, Chicago, USA) was used to perform the *t*-test, ANOVA and Tukey's *post hoc* tests at a confidence level of 95% to ascertain if any differences between the experimental groups were statistically significant.

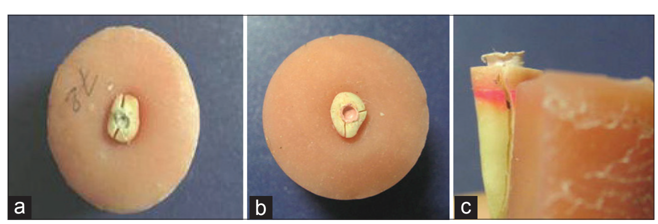

Figure 2: (a-c) Fractured root samples after force loading measurements

RESULTS

The mean and standard deviation (SD) values of the force load at fracture for each experimental group are shown in Table 1. Comparing the mean values of the loading force for the different experimental groups using the analysis of variances (ANOVA) test showed a significant difference between the experimental groups (ANOVA, $P < 0.0001$). Mean values of the loading force applied to the negative control group were the highest at 1.81 KN, whereas the mean values of the Resilon groups (Groups 4 and 5) at 1.13 and 1.54 KN were found to be higher than the GP groups (Groups 2 and 3) at 0.45 and 0.88 KN respectively. Among the experimental groups, the lowest mean value was recorded for the GP ProFile 0.04 taper (Group 2) and the positive control group. Applying Tukey's *post hoc* test to the same data showed that there was no statistical difference between the mean values of the negative control group and Group 5 ($P = 0.69$). Even among the experimental groups, Resilon ProFile 0.06 taper group (Group 5) was found to be the strongest group ($P = 0.001$) while the GP ProFile 0.04 taper group (Group 2) was statistically the weakest group ($P = 0.001$). An independent sample *t*-test was used to compare the mean values of GP with Resilon groups. The mean values for Resilon ProFile 0.04 (Group 4) and 0.06 (Group 5) taper were found to be significantly different from the GP groups ($P < 0.05$).

DISCUSSION

In light of the test results, the null hypothesis that there is no difference in the vertical forces of fracture between materials or taper preparation has to be rejected. In the presence of an adhesive interface, the higher load to fracture in Resilon-filled roots was expected. Although numerous studies have investigated the reinforcement of weak tooth structure and root canals by using adhesive materials, their reports appear to have conflicting results. In a recent study, Nagas, *et al.*,[12] compared the root reinforcement potential of three different intraorifice barriers (mineral trioxide aggregate, resin-modified glass ionomer, and fiber-reinforced composite) placed over root canals obturated with GP or Resilon. Fracture resistance of roots was significantly improved by the ionomer and composite intraorifice barrier but not by the type of obturation system used. Although these results lend support to the reinforcement through adhesion hypothesis, they may not be comparable to the present study since entire canals were obturated with no barriers and the canals were overtly flared before obturation.

Table 1: Mean and standard deviation of maximum loading force required to fracture the samples for each experimental group

Groups (each group *n*=10)	Mean (KN)†	SD
Control groups		
Negative control	1.81	±0.31
Positive control	0.27	±0.20
Gutta-percha proFile 0.04 taper	0.45	±0.23
Gutta-percha proFile 0.06 taper	0.88	±0.34
Resilon proFile 0.04 taper	1.13	±0.68
Resilon proFile 0.06 taper	1.54	±0.16

†Kilo Newton (KN), SD: Standard deviation

Other studies including Stuart *et al.*,[13] and Grande *et al.*,[14] demonstrated that the flexural properties of both Resilon and GP were too low to reinforce the root canals. The study by Grande *et al.*,[14] in 2007 was carried out on milled dentine samples with constant root canal diameter of 1.3 mm while Stuart *et al.*,[13] used unmodified roots but with a constant diameter or 1.5 mm. Although this may have provided good standardization for a small sample group, the results may not be as applicable for natural root surfaces with continuously tapering canals as used in the current study.

The results regarding Resilon were in accordance to two previous studies. Teixeira, *et al.*,[15] and Hammad, *et al.*,[11] reported higher mean fracture load values for resin-based obturation groups compared to the GP obturation groups. Although both studies did not use overtly flared canals, the results were similar. The present study adds new evidence that Resilon material increases the resistance to fracture of overtly flared root canals, especially when the canals are shaped by using ProFile 0.06 taper. This could be attributed to the increased bulk of Resilon material in obturated roots.

Experimental techniques for investigating root fracture have generally involved the generation of force over the obturated canal. Loading force measurements have been shown to be a powerful tool for investigating the mechanical properties of human teeth samples. A number of studies have used vertical loading force measurements to test fracture resistance successfully.[16,17] However, loading force experiments require controlled standards of sample preparation and experimental protocol to get meaningful results.

During selection of teeth, some dimensions of the specimens were controlled (e.g., root length and internal diameter and taper). Teeth were as similar as possible and were randomly assigned to groups. Sodium hypochlorite at 1% concentration was used as the irrigant of choice during preparation of the canals because it is the most commonly used irrigant. A low concentration was used to minimize the adverse effect on dentine mechanical properties. The canals were rinsed with EDTA as a final flush according to the manufacturer's instructions because any remaining sodium hypochlorite might inhibit the setting of resin materials. The loading force measurements in this study revealed a significant difference in resistance to fracture among experimental groups (ANOVA, $P < 0.0001$). These results suggest that Resilon increased the fracture resistance of endodontically treated roots to internally generated stresses.

The mean forces at fracture reported vary in previous studies,[11,18-21] and the mean forces at fracture reported in the study are well within that wide range. The wide range may be because of the type and dimensions of the teeth selected for the study, protocol followed for cleaning and shaping of the roots, and protocol followed for fracture resistance measuring.

Root canal instrumentation is an essential stage in endodontic treatment. Studies showed that instrumentation alone has been found to significantly weaken roots. It seems logical to remove as little dentine as possible during instrumentation without jeopardizing long-term success. Any material that can compensate for this weakening effect would be useful. It would be advantageous if the root canal obturation, in addition to providing an adequate seal, could contribute to the reduction in the incidence of vertical root fractures. In the current *in vitro* study the Resilon 0.06 taper group (Group 5) behaved similar in resistance to fracture as the unprepared control teeth. Though positive, these results warrant further testing to confirm any root reinforcement capability of Resilon in canals with thin and weak walls.

CONCLUSION

In the present study roots obturated with Resilon required a higher loading force to fracture compared to those obturated with GP. Pending further investigation, obturation with Resilon and resin-based sealer may increase the fracture resistance of overtly flared canals.

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