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Resistance to fracture of roots filled with different sealers

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The aim of this study was to compare the fracture resistance of roots filled with gutta percha (GP) and different root canal sealers. Fifty-five human maxillary central incisors were selected and randomly divided into three experimental groups (Groups 1–3) and two control groups (Groups 4 and 5). They were Group 1–15 root canals filled with an epoxy resin-based sealer (AH Plus) and GP, Group 2–15 root canals filled with a calcium silicate-based sealer (iRoot SP) and GP, Group 3: 15 root canals filled with another calcium silicate-based sealer (MTA Fillapex) and GP, Group 4: five roots were instrumented but not filled, and Group 5: five roots were neither instrumented nor filled. Compressive loading was carried out using a universal testing machine until fracture occurred. Force applied at time of fracture was recorded as fracture strength of specimen in Newtons. There were no significant differences in fracture strength among the three experimental groups ($p>0.05$), whose results were significantly superior to that of Group 4 ($p<0.05$). In conclusion, all the root canal sealers used in the present study increased the fracture resistance of instrumented root canals.

Keywords: Fracture resistance, Root canal sealer, Calcium silicate-based root canal sealers, Epoxy resin-based root canal sealers

INTRODUCTION

Root-filled teeth are more susceptible to fracture than vital teeth. Ironically, these teeth which were already compromised before root canal treatment are further weakened by the process. A few reasons contribute to the vulnerability of root-filled teeth, chief of which is root dentin dehydration after the endodontic procedures[1]. Other reasons that predispose root-filled teeth to fracture include brittleness of root-filled teeth because of loss of tooth structure[2,3], excessive pressure during filling procedures[1,4], and excessive widening of root canals[5].

After root canal treatment, the standard filling material is gutta percha. To obtain a hermetic seal, gutta percha is typically used in conjunction with root canal sealers because gutta percha is incapable of bonding to root canal walls. Root canal sealers not only fill the voids between gutta percha points, they also fill the voids between gutta percha and root canal walls[6].

Bondable root canal sealers purportedly improve the seal and fracture resistance of endodontically treated roots[7,8]. To date, conflicting results were reported from different research studies. On the one hand, one study[9] found no significant differences in fracture resistance between roots filled with a bondable root canal filling system, Epiphany, and those filled with gutta percha and an epoxy resin-based sealer, AH 26. On the other hand, a study[10] found that the fracture resistance of roots filled with gutta percha and AH 26 was superior to that of roots filled with the Epiphany system.

Recently, a new root canal sealer, iRoot SP (Innovative BioCreamix Inc, Vancouver, Canada), was introduced to the market. According to the manufacturer, iRoot SP is a convenient, pre-mixed, ready-to-use injectable white hydraulic cement paste developed for permanent root canal filling and sealing applications. Based on a calcium silicate composition, iRoot SP is an insoluble, radiopaque, and aluminum-free material which requires the presence of water to set and harden.

Another recently introduced root canal sealer is MTA Fillapex (Angelus Solucxoes Odontologicas, Londrina, Brazil). Based on an MTA (mineral trioxide aggregate) composition, other ingredients of MTA Fillapex include resins and silica (Table 1). According to the manufacturer, it has high radiopacity, low solubility in contact with tissue fluids, low expansion during setting, and excellent viscosity for insertion. It does not stain the tooth and promotes deposition of hard tissue at the root apex and perforation sites.

The purpose of the study was to compare the fracture resistance of roots filled with gutta percha and sealed with one of these three root canal sealers: an epoxy-based root canal sealer AH Plus (Dentsply DeTrey, Konstanz, Germany), a calcium silicate-based root canal sealer iRoot SP, and an MTA-based root canal sealer MTA Fillapex. The null hypothesis was that root canal sealers would not influence the fracture resistance of root-filled teeth.

MATERIALS AND METHODS

Root canal preparation

Fifty-five freshly extracted, intact, human maxillary central incisors with single straight root canals were selected for this study. They were stored in saline until use.

To ensure that incisor roots with standardized dimensions were used in this study, buccolingual and mesiodistal dimensions of the root canals were measured using a digital caliper. Crowns were sectioned at the cementoenamel junction, and the roots were adjusted to 13 mm in length. Working length was established to be 1 mm short of the apex.

The root canals were instrumented using ProTaper

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Table 1 Compositions of the root canal sealers examined in this study

Root canal sealer	Composition/Ingredients
AH Plus	Diepoxide, calcium tungstate, zirconium oxide, aerosol, 1-adamantane amine, TCD-diamine, dibenzyldiamine, aminoadamantane, pigments
iRoot SP	Zirconium oxide, calcium silicates, calcium phosphate, calcium hydroxide filler, thickening agents
MTA Fillapex	Salicylate resin, diluting resin, natural resin, bismuth trioxide, nanoparticulated silica, MTA, pigments

Table 2 Minimum, maximum, and mean values of fracture strength (in Newtons) for both experimental and control groups

Group	N	Mean value	Min	Max	SD
1[a]	15	1173.3	922.7	1613.7	265.54
2[a]	15	1031.1	616.5	1579.7	281.29
3[a]	15	1114.3	863.4	1386.8	165.18
4[b]	5	630.2	501.3	818.8	111.92
5[a]	5	1176.1	510.0	1675.6	329.57

SD: Standard deviation
Groups with the same letter are not significantly different among each other ($p>0.05$). a>b ($p<0.05$).

Ni-Ti rotary system (Dentsply Maillefer, Ballaigues, Switzerland). Master apical file was F3. Throughout instrumentation, irrigation was performed using 1 mL of 5% NaOCl after each file. Final irrigation was performed using 1 mL of 17% EDTA and copious amount of saline solution. The root canals were dried using paper points.

Experimental versus control groups

Following instrumentation, 45 prepared root canals were randomly divided into three experimental groups of 15 roots each as follows:

Group 1: Root canals were filled with gutta percha and AH Plus using a cold lateral condensation technique. AH Plus was prepared according to manufacturer's instructions and inserted into the empty canal space using a lentulo-spiral filler. Ingredients of AH Plus are shown in Table 1.

Group 2: Root canals were filled with gutta percha and iRoot SP using a cold lateral condensation technique. iRoot SP was prepared according to manufacturer's instructions and introduced into the empty canal space using a syringe. Ingredients of iRoot SP are shown in Table 1.

Group 3: Root canals were filled with gutta percha and MTA Fillapex using a cold lateral condensation technique. MTA Fillapex was prepared according to manufacturer's instructions and inserted into the empty canal space using a lentulo-spiral filler. Ingredients of MTA Fillapex are shown in Table 1.

The remaining 10 roots were randomly divided into two control groups of five roots each as follows:

Group 4: Roots were instrumented but not filled (negative control group).

Group 5: Roots were neither instrumented nor filled.

Fracture strength measurement

All filled roots of experimental groups, Groups 1 to 3, were stored at 37°C and 100% humidity for 7 days to allow the setting of root canal sealers. After setting, roots were embedded in acrylic molds: 7 mm of root was embedded in acrylic, while 6 mm of root protruded out of the mold.

Each acrylic mold was placed in a universal testing machine (Instron Corp., Canton, MA, USA). The upper part of the machine housed a round tip of 6 mm diameter, which was placed in contact with the occlusal surface of the root. Compressive loading was applied at a crosshead speed of 1 mm min^{-1} at an angle of 45° until fracture occurred. Load value at fracture, which was recorded as fracture strength of specimen, was recorded in Newtons (N). Statistical analysis was performed using ANOVA and Tukey's B test.

RESULTS

Table 2 shows the mean fracture strengths of Groups 1 to 5. When compared to the negative control group (Group 4), the mean fracture strength of each experimental group, *i.e.*, Group1 to Group 3, was significantly higher ($p<0.05$).

DISCUSSION

Weakening effects of root canal therapy on already weakened teeth

During root canal treatment, biomechanical preparation of the root canal system entails mechanical instrumentation to remove infected pulp and dentin, followed by irrigation with chemical substances to clean and disinfect the root canal system. Excessive removal of tooth substance during mechanical instrumentation and the use of unnecessary force during obturation decrease the fracture resistance of root-filled teeth[11]. Use of root canal irrigants results in dentin dehydration, reducing the elastic modulus and flexural strength of dentin, and unwittingly contributes to the weakening of root-treated teeth[12].

The purpose of root canal filling is to reinforce and strengthen a weakened root against fracture. An ideal root canal filling fills the entire root canal system three-dimensionally. To achieve a dense, three-dimensional obturation, gutta percha cones must be used with root canal sealers. Root canal sealers not only provide adhesion to both gutta percha and root dentin[6], they also fill the voids and minor discrepancies between gutta percha cones and root canal wall.

Standardization of experimental teeth and experimental method in this study

The present study compared the fracture resistance of endodontically treated teeth filled with different root canal sealers. Previous studies have shown the difficulty of obtaining uniform fracture strengths for human teeth because of natural variations in tooth morphology[13,14]. Emulating the experimental protocols of Karapinar Kazandag *et al.*[5] and Ulusoy *et al.*[10], optimum care was taken in this study to standardize the experimental teeth according to their tooth sizes and dimensions and working length measurements.

Further, standardized instrumentation, irrigation, and obturation procedures were used for all the experimental groups. According to Versluis *et al.*[15], root canal preparations that resulted in a round cross-section led to more uniform stress distributions within a root during filling, hence reducing fracture susceptibility. For this reason, Protaper Ni-Ti rotary system was used in this study to produce round-shaped canals. After the instrumentation phase, final irrigation was done using 17% EDTA to remove the smear layer. Many advantages stem from smear layer removal: improved adhesion and adaptation of the root canal sealer to the root canal wall, and thereby increased sealing efficiency[16-18]. Also in this study, a final rinse using distilled water was carried out to neutralize the effects of root canal irrigants.

For fracture strength measurement in many studies, loading force was applied in a vertical direction. This was done with the view that a vertical force applied parallel to the long axis of a tooth produced more uniform stress distributions[19-21]. However, it has been reported that applying a force at different angles to the long axis of a tooth is more likely to simulate occlusal loading in clinical conditions[22]. Therefore in the present study, a single load to fracture was applied at a 45° angle with a crosshead speed of 1 mm min^{-1} using a universal testing machine (Instron Corp., Canton, MA, USA).

Effect of root canal sealers on fracture resistance of root-filled teeth

Today, commonly used root canal sealers are based on polyketone, glass ionomer, zinc oxide-eugenol (ZnOE), epoxy resin, calcium hydroxide, methacrylate resins, mineral trioxide aggregate (MTA), or silicone[23].

Adhesion between dental structures and resin-based sealers is the result of a physicochemical interaction across the interface, developing a bond and allowing the union between filling material and root canal wall[24,25]. In static circumstances, the adhesion provided by sealers eliminates spaces that might otherwise allow fluids to infiltrate into the sealer-dentin interface. In dynamic situations, the adhesion is necessary to avoid dislodgement of the filling material during operative procedures[26], hence reducing the risk of contamination and re-infection of the tooth.

In many studies, epoxy resin-based sealers showed higher adhesion to root canal dentin and deeper penetration into the dentinal tubules than glass ionomer- and ZnOE-based sealers[25,27-29]. This meant that retention of the filling material might be improved by mechanically locking it into place, hence reinforcing root canal dentin to increase its fracture resistance. With much attention on the adhesive properties and sealing ability of epoxy resin-based root canal sealers, the effect of AH Plus on the fracture resistance of root-filled teeth was compared with other types of root canal sealers in this study.

iRoot SP is a newly introduced calcium silicate-based root canal sealer. iRoot SP requires no additional curing agents and no mixing. It also delivers a consistent, homogeneous product for filling root canals with or without gutta percha points. Other favorable features of this sealer include osteoconductivity, hydrophilicity, adhesiveness and chemical bonding to root canal dentinal walls. In several studies, it was shown that chemical bonding to root dentin improved the resistance of endodontically treated teeth against root fractures[7,8,30].

Another newly introduced root canal sealer is MTA Fillapex. Its MTA-based composition contains salicylate resin, diluting resin, natural resin, nanoparticulated silica, and bismuth trioxide. In several studies, it was shown that MTA as a root canal filling material strengthened the root against fracture[31,32]. This could be related to the phenomenon of delayed strength development of MTA, which occurs after 24 h of

setting[33].

A survey of published literature showed that the reinforcing effect of AH Plus root canal sealer on fracture resistance has already been evaluated in numerous studies[5,27,34,35]. In the present study, no differences in fracture strength were found among roots filled with AH Plus, iRoot SP, and MTA Fillapex. The results of this study agreed with those of Karapinar Kazandag *et al.*[5] and and Cobankara *et al.*[30] in that all the experimental groups showed significantly superior fracture resistance than the negative control group. On the other hand, our results contradicted with those of Grande *et al.*[36] and Kim *et al.*[37], in that they found no clear benefits with the use of root canal sealers in improving the fracture resistance of root canal dentin.

According to Andreasen *et al.*[31] and Cauwels *et al.*[32], MTA increased the fracture resistance of immature teeth. In the present study, MTA-based root canal sealer MTA Fillapex showed significantly higher fracture resistance than the negative control group and was not significantly different from AH Plus and iRoot SP. This could be due to the presence of resins and MTA in the composition of MTA Fillapex.

iRoot SP is another recently introduced root canal sealer based on a calcium silicate composition. It is also a resin-based sealer with good adhesive property, thus effectively reinforcing the roots in this study. However, in view of the conflicting fracture resistance results yielded by different studies, more investigations are needed to evaluate the root-reinforcing capabilities of iRoot SP and MTA Fillapex root canal sealers.

CONCLUSIONS

All the three root canal sealers examined in this study strengthened the prepared root canals with increased fracture resistance.

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