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Original Research

Comparative Evaluation of Fracture Resistance of Endodontically Treated Teeth Obturated with Resin Based Adhesive Sealers with Conventional Obturation Technique: An *In vitro* Study

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Abstract:

Background: To compare fracture resistance of endodontically treated teeth obturated with different resin-based adhesive sealers with a conventional obturation technique.

Materials and Methods: A total of 60 Single canaled teeth were divided into five groups. The first group was taken as a negative control. The rest of the groups were shaped using ProFile rotary files (Dentsply Maillefer, Ballaigues, Switzerland). The second group was obturated with gutta-percha and a ZOE-based sealer Endoflas FS (Sanlor Dental Products, USA). The third group was obturated with gutta-percha and an epoxy-based sealer AH Plus (Dentsply, DeTrey, Germany). The fourth group was obturated with Resilon (Pentron Clinical Technologies, Wallingford, CT) and RealSeal sealer (Pentron Clinical Technologies). The fifth group was obturated with EndoREZ points and EndoREZ sealer (both from Ultradent, South Jordan, UT). Roots were then embedded into acrylic blocks and were then fixed into a material testing system and loaded with a stainless steel pin with a crosshead speed of 5 mm/min until fracture. The load at which the specimen fractured was recorded in Newtons.

Results: It was found that forces at fracture were statistically significant for the newer resin systems, Resilon, and EndoREZ.

Conclusion: It was concluded that roots obturated with newer resin systems (Resilon and EndoREZ) enhanced the root strength almost up to the level of the intact roots.

Key Words: AH Plus, endodontically treated teeth, EndoREZ, fracture resistance, obturation, Resilon, resin-based sealers, vertical fracture

Introduction

The major objectives of root canal therapy are removal of the pathologic pulp, shaping and cleaning of the root canal system, disinfection of the contaminated root canals and three dimensional obturation to prevent reinfection.[1]

The success of endodontic therapy depends on adequate access, thorough biomechanical preparation and proper obturation of the root canal system.

Endodontically treated teeth are widely considered to be more susceptible to fracture than vital teeth. The reasons most often reported have been the removal of tooth structure during endodontic therapy, dehydration of dentin after endodontic therapy and excessive pressure during obturation.[2,3]

The strength of the endodontically treated teeth is directly related to the method of canal preparation and the amount of remaining sound tooth structure. It is observed that the greatest incidence of vertical root fracture occurs in teeth that have undergone endodontic therapy.[4] Vertical root fracture is a longitudinal fracture of the root, extending throughout the entire thickness of dentin from the root canal to the periodontium. It is of serious clinical concern and has an unfavorable prognosis resulting in extraction of the tooth or resection of the affected root.[5,6]

Although obturation may not necessarily be the most critical stage in root canal therapy, it should still be performed according to the highest clinical standards. Gutta-percha has widely been accepted for years as the gold standard filling material to obturate root canals. Furthermore, the adhesive strength between the root canal walls, endodontic sealers, and gutta-percha was found to be very weak.[7]

Although very few materials have seriously challenged gutta-percha and sealer in majority of filling situations, research continues to find alternatives that may seal better and also mechanically reinforce compromised roots.[7]

The bonding concept of the root filling material is hampered by the lack of a chemical union between the polyisoprene component of gutta-percha and methacrylate-based resin sealers.[8]

Recently, two challenging strategies have been employed to effectively reinforce the endodontically treated tooth structure.

A new material Resilon (Pentron Clinical Technologies, Wallington, CT) was introduced as a better alternative to gutta-percha. This synthetic polymer claimed not only to provide a better seal but also reinforces the tooth structure through a combination of primer, dual cure sealer and resin obturating material. The polyester chemistry containing bioactive and radiopaque fillers made it to possess better handling characteristics and look alike gutta-percha. In addition, when used in conjunction with a resin-based sealant or bonding agent it forms a monoblock within the canals that bonds to the dentinal walls, it appears logical that they have the potential to strengthen the walls against fracture.[1,8]

A second strategy has been employed in which an unusual resin is created by first reacting one of the isocyanato groups of a diisocyanate with the hydroxyl group of a hydroxyl terminated polybutadiene as the latter is bondable to hydrophobic polyisoprene. This is followed by grafting of a hydrophilic methacrylate functional group to the other isocyanato group of the diisocyanate producing a gutta-percha resin coating that is bondable to a methacrylate-based resin sealer. The resin coated gutta-percha is recommended to be used with a recently modified patented version of a hydrophilic methacrylate-based dual-cured resin sealer (EndoREZ).[9]

In the light of incidence of vertical root fractures associated with gutta-percha filling techniques, this study was undertaken to compare the fracture resistance of roots endodontically treated with different resin-based adhesive sealers with conventional lateral condensation technique.

Materials and Methods

A total of 60 single canalled extracted maxillary anterior teeth, caries free and periodontally compromised, which was confirmed by the Department of Periodontology, KM Shah Dental College, were collected and cleaned of soft tissue debris and calculus and stored in phosphate buffered saline (PBS, pH 7.2) containing 0.1% sodium azide to inhibit bacterial growth for a maximum of 5 days. Caries free teeth, with a single root and a single, straight canal confirmed radiographically, completely formed apices with root lengths ranging from 14 to 16 mm and bucco lingual diameter ranging from 6 to 8 mm were included for the present study. All the teeth were carefully examined under ×16 magnifications with the help of digital operating microscope (Seiler Dental Microscope, Seiler Instruments Inc., St. Louis, USA) to rule out preexisting fractures and all unacceptable ones were discarded. The selected teeth were sectioned at the cement-enamel junction with a diamond disk operated on a slow speed micromotor hand piece under a constant water coolant flow. The root specimens were then stored in sterile water until treatment. Roots were randomly allocated into five groups each group containing twelve specimens. The first group served as a negative control group containing the roots neither instrumented nor obturated. In the remaining four groups, access cavities were prepared with diamond burs. The working length was determined by introducing a size 10 K file into the canal until it exited from the apex and the final working length was set 1 mm short of that length. After the introduction of hand files and establishment of a glide path, an automated torque control Endomotor with an attached reduction gear hand piece was used with ProFile Rotary Series to clean and shape the root canals using Glyde as a lubricant and a chelator (Figure 1).

ProFile Orifice Shapers (O.S), ProFile 0.06 and ProFile 0.04 tapers, were the three types of instruments used in the shaping of root canals. Instrumentation was initiated by the introduction of ProFile O.S 4 (#0.07/50) and ProFile O.S 3 (#0.06/40) files until the point of resistance without exerting any pressure. Roots were then submitted to chemomechanical preparation with the following sequence: #30/.06, #25/.06, #20/.06, #30/.04, #25/.04, #20/.04, and finally #30/.06. In between each preparation 2 ml 1% sodium hypochlorite was used as an irrigant. Furthermore, a small size 10 no. file was introduced to maintain patency of the apical constriction. The canals were thus prepared to a final taper #30/.06. After completion of instrumentation, all specimens received a final flush of 5 ml 17% of EDTA irrigating solution following manufacturer's instructions followed by 5 ml of 2.5% NaOCl solution in order to remove the smear layer. This was followed by a final irrigation with 5 ml normal saline. Each of the root canals were dried with at least 5 paper points.

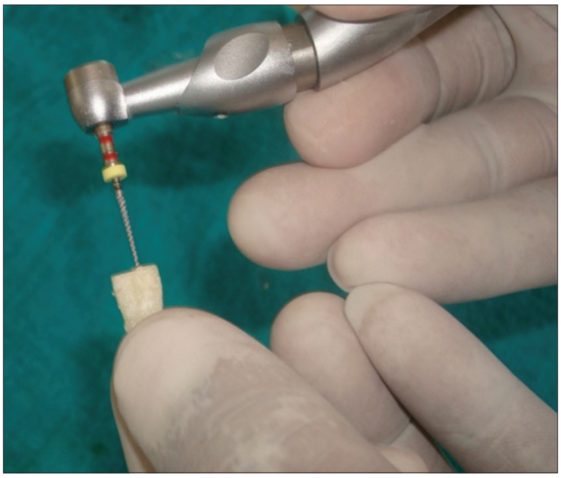


Figure 1: Instrumentation of the root canals with ProFile rotary series instruments and torque control Endomotor with a mounted reduction gear hand piece.

Then the specimens were randomly assigned into five experimental groups (*n* =12) per group as follows.

Group I: Control group

Neither instrumentation nor obturation was done in the samples in this group; the root canal openings were sealed with Cavit.

Group II: Endoflas FS group

These teeth received a root filling by cold lateral condensation technique with gutta-percha cones and Endoflas FS (ZOE-based sealer) (Sanlor Dental Products, USA).

Group III: AH Plus group

The third group received a root filling by cold lateral condensation technique with gutta-percha and AH Plus (Dentsply, DeTrey, Germeny) an epoxy resin-based root canal sealer.

Group IV: RealSeal group

The fourth group received a root filling by lateral condensation using RealSeal Resilon points and RealSeal dual cure resin sealer (Pentron Clinical Technologies, Wallingford, CT) (Figure 2). After checking the snug fit of the master Resilon cone, the RealSeal primer was dispensed onto a microbrush available in the kit (Figure 3), the excess removed by using paper points. The apical third of the master cone was coated with the sealer and placed into canal and then a size 20 finger spreader was inserted, rotated and withdrawn. An accessory Resilon cone coated with a thin layer of sealer was placed into the space created by the spreader and process repeated until the canal was completely obturated. The coronal portion of the sealer was subsequently light cured for 40 s, to stabilize the material, enabling excess Resilon to be removed with a hot instrument.

Figure 2: RealSeal Resilon points and RealSeal dual cure resin sealer (Pentron Clinical Technologies, Wallingford, CT).

Figure 3: The RealSeal primer dispensed on to a microbrush, the primer applied on the root canal walls with the help of the microbrush, excess primer was removed by using paper points.

Group V: EndoREZ group

The fifth group was root canals filled with cold lateral condensation with EndoREZ resin coated gutta-percha points and EndoREZ resin-based sealer (Ultradent, South Jordan, USA) (Figure 4). After checking the snug fit of the master EndoREZ cone, the mixed sealer was injected into the root canal via 30-gauge NaviTip (Ultradent) attached to skini syringe (Ultradent) (Figure 5). The former was inserted to 2-3 mm short of working length and slowly withdrawn to fill the entire canal with sealer avoiding entrapment of air. The prefit master cone (0.06 taper resin coated, ISO No. 30) was then inserted into the canal to the working length, followed by the passive placement of multiple, accessory 0.02 taper, No. #20 resin coated gutta-percha cones, to reduce the sealer volume and to avoid scraping off of the resin coating with the use of spreader/plugger. The coronal portion of the sealer was subsequently light cured for 40 s, to stabilize the material, enabling excess gutta-percha to be removed with a hot instrument.

All the filled root specimens were subsequently sealed with Cavit temporary filling material. All roots were kept at 37°C with 100% humidity for 2 weeks to allow the sealers to set completely after which the samples were prepared to be subjected to mechanical strength testing. An acrylic block with a simulated periodontal ligament created with the help of vinyl polysiloxane light body rubber base impression material was fabricated to allow for adequate stabilization of the specimens during testing procedures. After the resin had set, the blocks with embedded roots were mounted on to the loading frame of Material Testing System (Minneapolis, Minnesota, USA) (Figure 6). A stainless steel pin simulating a size 40 spreader was manufactured and fixed into the cross head and placed directly above the root canal orifice. Extreme care was taken to ensure that all the roots were embedded in an exact line parallel to the long axis of the pin in order to prevent any unusual oblique stresses on the root canal walls. The testing machine was calibrated with these components to vertically drive the pin into the canal at a cross head speed of 5 mm/min during which it penetrated the root canal and force was applied to the root until it fractured.

Fracture was defined as the point at which a sharp and an instantaneous drop>25% of the applied force was observed for each root and so the machine was adjusted to terminate the test when a 25% reduction of force was observed. The force

Figure 4: EndoREZ resin coated gutta-percha points and EndoREZ resin-based sealer (Ultradent, South Jordan, USA).

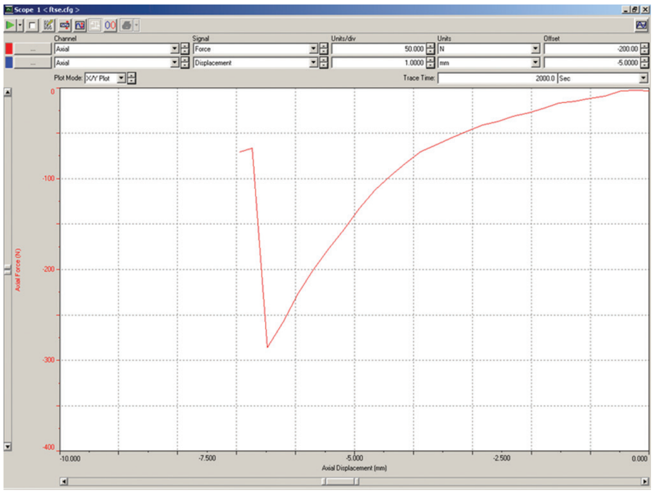
Figure 5: Navitips of different sizes and ultramixer for dispensing the sealer.

Figure 6: The block with embedded root were mounted on to the loading frame of material testing system.

applied to the root canal was recorded in the form of a graphical representation in addition to the continuous digital display of different test parameters (Graph 1). Throughout the test, the roots were kept hydrated. The loads at which different root specimens fractured were recorded in Newtons and the data were subjected to statistical analysis.

Observations and Results

Firstly one-way ANOVA test followed by *post-hoc* Scheffe multiple comparison tests on both the variables of length and faciolingual diameters of different samples were performed and it was concluded that all the samples of the experimental groups were completely well-balanced concerning the defined constraints.



Graph 1: A complete graphical representation of the entire testing procedure on a particular specimen (Axial force vs. Displacement graph).

The results of fracture resistance obtained were measured in Newtons for each specimen has been tabulated in (Table 1).

The descriptive statistics of loads of various specimens of different groups are mentioned in (Table 2).

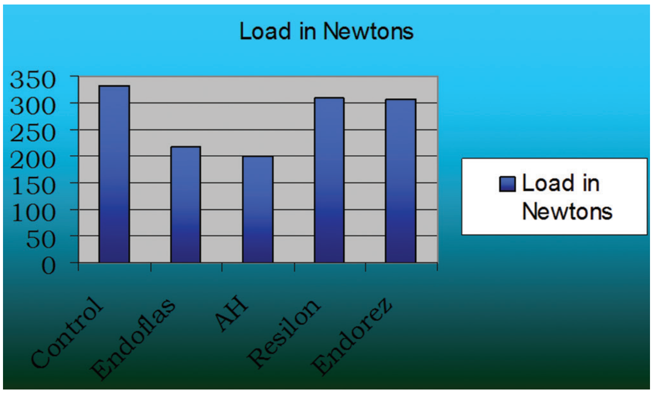
A graphical representation of the mean load values to fracture roots obturated with different sealers is shown below (Graph 2).

Considering this statistical situation a more detailed analysis one-way ANOVA test was called for (Table 3).

Further this was substantiated with multiple comparisons through *post-hoc* Tukey HSD multiple comparison test (Table 4).

One-way ANOVA revealed highly significant difference between groups ($P < 0.0001$). Statistically significant difference is noted in fracture resistance values of control group and certain test groups i.e., the control group displayed significantly higher values than both the gutta-percha groups (Group II and III) ($P < 0.05$). While groups IV and V displayed values lower than the control group but were statistically insignificant ($P > 0.05$).

Among the test groups, Resilon group (Group IV) and EndoREZ group (Group V) displayed significantly higher values than the gutta-percha groups (Group II - Endoflas and Group III - AH Plus) ($P < 0.05$). Furthermore, there



Graph 2: A graphical representation of the mean load values to fracture roots obturated with different sealers.

Table 1: Values of load in Newtons required to fracture various root specimens of different groups.

Specimen no.	Control (N)	Endoflas (N)	AH Plus (N)	RealSeal (N)	EndoREZ (N)
1	289	166	191	359	260
2	263	189	221	310	319
3	358	215	240	272	357
4	378	220	253	342	304
5	390	215	199	316	316
6	278	232	189	289	323
7	292	202	237	305	310
8	323	182	217	326	283
9	382	209	227	359	290
10	369	172	198	310	316

Table 2: Descriptive statistics of the loads to fracture different samples.

Specimen group	Number	Minimum load	Maximum load	Mean	Standard deviation
Control	10	263	390	332.2	48.57022
Endoflas	10	189	253	217.2	22.32487
AH Plus	10	166	232	200.2	21.96866
Resilon	10	260	359	310	30.27283
EndoREZ	10	260	357	307.2	25.99487
Valid N (list wise)	10				

Table 3: Application of one-way ANOVA.

ANOVA dependent variable: AH	Sum of squares	Degree of freedom	Mean square	*F* value	Significant
Between groups	144561.1	4	36140.28	36.63658	0.000
Within groups	44390.4	45	986.4533		
Total	188951.5	49			

was no statistically significant difference between the values of Group IV and Group V ($P > 0.05$). Similarly, there was no statistically significant difference between the values of Group II and Group III ($P > 0.05$).

Discussion

The primary goal of endodontics is not only to restore the tooth structure but also to increase the inherent strength of the remaining tooth structure. Although the use of gutta-percha with an insoluble root canal sealer can be seen as a gold standard of root canal fillings, the ability of these materials to reinforce an endodontically treated root is discussed with controversy.

Certain resin-based materials have been proposed since long to reinforce the endodontically treated teeth like Diaket,[10] Hydron,[11] Ketac Endo Aplicap[12] AH 26, AH Plus[13,14] Endoresin.[15,16]

The development of bonded obturating materials is in congruence with the efforts to provide a more effective seal apically as well as coronally. The adhesion between dental structures and resin-based sealers is the result of a physicochemical interaction across the interface, allowing the union between filling material and root canal wall.[17,18] This process is important in static and dynamic situations. In static circumstances, the adhesion eliminates spaces that allow the infiltration of fluids into the sealer/dentine interface.[19] In dynamic situations, the adhesion is necessary to avoid the sealer dislodgment during operative procedures. Therefore, the endodontic filling materials may enhance the ability of root filled teeth to resist fracture.[20,21]

Because the resin core, sealant, and the dentinal wall all are "attached," it appears logical that they have the potential to strengthen the walls against fracture. However, very few studies have been conducted on this aspect to support the hypothesis regarding the root reinforcement ability of the newer resin-based systems.

All the root canals were enlarged by a single operator to minimize operator variation.[13] Canal shape after preparation with hand files can be quite irregular.[22] From a fracture mechanics point of view, the presence of structural defects, cracks or canal irregularities is likely to play a major role in determining fracture strength.[23] Rotary NiTi canal preparation using ProFile rotary instruments did not reduce fracture susceptibility of the root and also the roots were significantly weakened by the preparation with greater taper instruments.[24] During the root canal preparation freshly prepared 1% sodium hypochlorite was used as an irrigant as it is the most commonly used irrigant, and a low concentration was used to minimize the adverse effect on dentin mechanical properties.[1]

Final rinse was done with EDTA followed by NaOCl to enhance the bonding of the materials tested to the dentinal surface of the root. This was done in accordance with the protocol recommended by Weiger *et al.* to use EDTA followed by NaOCl, which seemed to optimize adhesion of sealers to the root canal walls.[25]

Root canal obturation has been implicated as the major cause of vertical root fracture. In lateral condensation, the strain is

Table 4: Tukey HSD multiple comparison test for comparing several test groups.

Multiple comparisons: Dependent variable: AH

(I) Type of material	(J) Type of material	Mean difference (I-J)	Standard error	Significant	95% Confidence interval	
					Lower boundary	Upper boundary
Control	Endoflas	132*	14.04602	0.000	92.08894	171.9111
	AH Plus	115*	14.04602	0.000	75.08894	154.9111
	Resilon	22.2	14.04602	0.517	−17.7111	62.11106
	EndoREZ	25	14.04602	0.398	−14.9111	64.91106
Endoflas	Control	−132*	14.04602	0.000	−171.911	−92.0889
	AH Plus	−17	14.04602	0.745	−56.9111	22.91106
	Resilon	−109.8*	14.04602	0.000	−149.711	−69.8889
	EndoREZ	−107*	14.04602	0.000	−146.911	−67.0889
AH Plus	Control	−115*	14.04602	0.000	−154.911	−75.0889
	Endoflas	17	14.04602	0.745	−22.9111	56.91106
	Resilon	−92.8*	14.04602	0.000	−132.711	−52.8889
	EndoREZ	−90*	14.04602	0.000	−129.911	−50.0889
Resilon	Control	−22.2	14.04602	0.517	−62.1111	17.71106
	Endoflas	109.8*	14.04602	0.000	69.88894	149.7111
	AH Plus	92.8*	14.04602	0.000	52.88894	132.7111
	EndoREZ	2.8	14.04602	1.000	−37.1111	42.71106
EndoREZ	Control	−25	14.04602	0.398	−64.9111	14.91106
	Endoflas	107*	14.04602	0.000	67.08894	146.9111
	AH Plus	90*	14.04602	0.000	50.08894	129.9111
	Resilon	−2.8	14.04602	1.000	−42.7111	37.11106

*The mean difference is significant at the 0.05 level

generated by the wedging effect of the spreader because it laterally compacts the gutta-percha and adapts it to canal wall while vertical condensation creates strains as the mass of gutta-percha is compacted apically with pluggers under consistent vertical load.[5,26] However, lateral condensation technique was used in this study because it is a more widely recommended and a proven classic technique,[7] which facilitates comparison with previous studies.[1,27] Furthermore, the principal reason is that EndoREZ system is only provided in the form of cones and not yet available in any other form for vertical or thermal condensation.[3]

Strength testing is the methodology that has been used to study the influence of filling materials on the fracture resistance of teeth submitted to root canal treatment[9,12,28] as performed in this study. In this study, Material Testing System, a very precise testing machine was used. The force was applied along the long axis of the root with a stainless steel pin, which produced root fracture when contact was made between the pin and the walls of the canal opening. The method adapted in this study to fracture the root specimens was chosen because it provided force distribution from inside the root canal and fractures occurring as a result of forces transmitted via the obturating material.[5] This resembled root fracture of endodontic origin or from a post.[27] Stresses generated from inside the root canal were transmitted through the root to the surface where the interdentin bonding failed.[29] The test was terminated after a 25% drop in the maximum force recorded similar to that used in the previous studies.[1,8,13]

The method presented in this study for measuring the fracture strength of obturating material has proven to be effective and reproducible. It is simple and easy to duplicate and reliable in accordance with the results of previously published findings.

Conclusions

The following conclusions were drawn from this study:

1. Intact roots have greater fracture resistance than that of the instrumented roots.
2. Intact roots have significantly greater fracture resistance than the gutta-percha filled roots.
3. The roots obturated with both the newer resin-based adhesive systems i.e. RealSeal and EndoREZ have significantly greater fracture resistance than the gutta-percha filled roots.
4. There is no statistically significant difference in fracture resistance of the roots obturated with gutta-percha/Endoflas FS and gutta-percha/AH Plus sealer.
5. There is no statistically significant difference in fracture resistance of roots obturated with Resilon/RealSeal sealer and the intact roots.
6. There is no statistically significant difference in fracture resistance of roots obturated with Resin coated gutta-percha/EndoREZ sealer and the intact roots.
7. There is no statistically significant difference in fracture resistance of roots obturated with Resilon/RealSeal sealer, and Resin coated gutta-percha/EndoREZ sealer.

Although the present results concerning the adhesive root canal filling materials RealSeal and EndoREZ to reinforce the endodontically treated roots are very promising some care should be taken in the transfer of these findings to the long term clinical situation. Further *in vivo* and biocompatibility tests involving newer resin-based systems will be necessary to determine whether the results *in vitro* will be validated. Clinical long-term studies are necessary to collect evidence-based data to support the confident use of these materials.

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