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Original Research Article

Quantitative and Qualitative Assessment of Sealing Ability of Different Root Canal Sealing Materials

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ABSTRACT

Background: The use of resin-based dentin adhesives has become routine in dentistry. As a result, marginal leakage in conjunction with bonded restorations is greatly reduced, however true adhesive restorative materials do not exist at present, and the bonding is due to micromechanical retention of the resinous material to the tooth. As some endodontic sealing materials have high bond strength to dentin but may suffer from solubility and improper sealing ability. Consequently, evaluation of some properties of these materials may be advantageous for proper selection of which type to be used.
Aim: The aim of this study was to evaluate the sealing capacity and the bond strength of two different types of root canal sealing materials.
Methodology: A total of 20 single-rooted human mandibular premolar teeth with single canals were instrumented using step back technique. The prepared canals were obturated with lateral compaction technique using gutta percha and two different types of sealers; 10 with resin- based sealer (Group 1) and 10 with silicone -based sealer (Group 2). Each root was sectioned horizontally into 2 slices, each slice is 2mm, the coronal part just below the cemento-enamel junction was used in the push-out shear bond strength test. The following 2 mm slice of the filled roots was used in the sealing capacity or permeability test, using fluid filtration device. Permeability was measured by tracing the displacement of an air bubble on top of a millimeter scale for 24 hours. A random disc from each group was kept for qualitative evaluation of dentin\sealer interfaces with the scanning electron microscope. The results were subjected to statistical analysis using Kruskal Wallis and Mann Whitney tests.
Results: The data indicates that the mean fluid leakage value of the silicone -based sealer (Group 2) was less than that of the resin- based sealer (Group 1). While the resin- based sealer (Group 1) exhibited higher statistically significant mean shear bond strength than silicone -based sealer.
Conclusion: Improved bonding of sealers to dentin does not necessarily mean the improvement of sealing ability.

Keywords: Fluid filtration device, sealing capacity, sealers.

INTRODUCTION

Success in endodontic treatment depends to a great extent on complete obturation of root canal with an inert filling material. The most common form of endodontic treatment uses a combination of gutta percha cones, which is considered as an impermeable core material, and a sealer to achieve a tight apical and coronal seal. [1]

A great variety of endodontic sealers is commercially available which is usually categorized according to the main components, as zinc oxide and eugenol, calcium hydroxide, glass ionomer, resin and silicone based sealers. [2]

The main clinical requirements of a root canal sealer are good tissue compatibility and a lasting tightness of the root canal. Tightness mainly depends on dimensional stability like absence of shrinkage, expansion and solubility as well as adhesion to both dentin and applied cones. [2]

The use of resin-based dentin adhesives has become routine in dentistry. As a result, marginal leakage in conjunction with bonded restorations is greatly reduced, however true adhesive restorative materials do not exist at present, and the bonding is due to micromechanical retention of the resinous material to the tooth. [3]

Unfortunately, there is still a controversy about which type to be used successfully as a root canal sealing material. As some endodontic sealing materials have high bond strength to dentin but may suffer from solubility and improper sealing ability. Consequently, evaluation of some properties of these materials may be advantageous for proper selection of which type to be used.

As few studies concerned with the permeability of recent endodontic sealers, this imposes the need to evaluate this property and compare them with other sealers.

Aim of Study

The aim of this study was to evaluate the sealing capacity and bond strength of two different types of root canal sealing materials.

MATERIALS AND METHODS

Materials

Two types of commercially available root canal sealing materials were used in this study; one resin -based root canal sealing material, and one silicone -based root canal sealing material.

One type of commercially available gutta percha was used in this study as an endodontic obturating material.

Methods

Sample preparation: A total of 20 freshly extracted straight single-rooted human mandibular premolar teeth with single canals from orthodontic patients aged between 15 to 25 years, were used in this study. The selected teeth had approximately the same dimensions. All root canals were instrumented using step back technique, The apical portion of all the root canals, were enlarged up to size 50 master apical file at the working length. Between the use of each file or bur, canals were irrigated with 5 ml of5.25 % NaOCl.

After the preparation was completed, each root canal was rinsed with 3 ml of 17% ethylene diamine tetra acetic acid (EDTA) for 1 min. to remove the smear layer and to minimize the residual effect of NaOCl on free radical polymerization. The canals were flushed with a 10 ml distilled water to remove any remnant of the irrigating solutions. The root canals were dried with paper points before filling. The teeth were kept moist at all times by wrapping them in saline soaked gauze.

The lateral condensation technique was used to obturate the prepared root canals using ISO standardized gutta percha points with 0.02mm taper. The root canal sealing materials used in this study were mixed and applied according to the manufacturer instructions. Teeth were divided into two groups (10 each). Each group was used with one type of the two tested root canal sealers, Group (1) with resin- based sealer and Group (2) with silicone based sealer. The sealers were allowed to set for 7 days to assure complete setting, at 37˚C in an incubator. [4]

Each root was sectioned horizontally using 7/8 inch diamond disc mounted on a grinding machine and under water coolant to create 2 slices, each slice is 2 mm, the coronal part just below the cemento-enamel junction, to be used in the push-out shear bond strength test and the other 2mm slice, to be used in the sealing capacity test.

*Testing:*1) Sealing capacity: The external surfaces in all the specimens were completely sealed by applying a double coat of nail varnish, except that of the root canal opening, to limit the passage of fluid across the dentinal tubules and assure that any fluid flow measured was limited to the root canals only.

A fluid filtration device was used to measure fluid penetration through the root canals induced by hydrostatic pressure. This was done by following the progress of an air bubble travelling within a 25 μL micropipette, The apparatus was constructed according to the device designed by Pashley and Galloway in 1985, [5] with slight modification to fit the test. The apparatus was connected to an electric pump to provide controlled pressure (160mm Hg). [6,7]

The fluid filtration device included ten pairs of split teflon chambers, the split chamber device consists of two parts, female and male parts which were attached to each other by screwing action. Pairs of identical “O” rubber rings that snugly fit within the female part were prepared to adapt the discs and seal the chamber. Each rubber ring has a central hole (1mm in diameter) to limit the tested surface area of each root dentin disc. Equal lengths of rubber tubes were used to connect the female parts to the metallic mother rod of the filtration device from one side. Similarly, these rubber tubes connect the male parts of the device to graduated 25µl glass micropipettes from the other side. All the apparatus connections were immersed in distilled water.

Care was taken to fill all the inner parts of the assembly with distilled water with minimal presence of air bubbles. The temperature of the apparatus was strictly maintained at 25˚C. [7]

Mechanism of measuring the Sealer permeability

Before beginning the test, the discs were placed in the split chamber device between the two “O” rubber rings with the apical side of the discs facing the pump side (inlet) and the coronal side facing the pipette side of the chamber (outlet).

After mounting all the discs into their split chamber, a pre-applied pressure was performed to check for any leaks while ultra-tight fittings were used throughout the whole system. The pre-applied pressure also forced the fluid into any voids present in the root filling. If leaks were observed in the fittings during this pretest, sealing of these leaks was performed meticulously. Such measures helped to ensure that any subsequent fluid movement was due to leakage in the canal itself and not because of flaws in the technique.

An air bubble was created by raising each micropipette out of the water bath for one second for suction of air, and then letting it down again into the water. An air bubble was formed in each pipette, and its location was determined for every specimen and recorded.

The adjusted hydrostatic pressure was applied, through the female part of the chamber, to the apical side of the root and the fluid was forced through the voids along the root canal filling. The fluid flowed out from the coronal canal opening of the root specimens through the male part displacing the air bubble in the glass micropipette. [8,9]

In a pilot study, that was done to standardize the time interval used for measurement of fluid filtration, 24 hours interval was found to be convenient. This time interval was selected as it was the minimal time to produce a perceptible and measurable air bubble movement in all the specimens. Thus, pressure was applied for 24 hours then the pump was switched off. The location of the air bubble was re-determined and recorded in mm. The volume of the fluid transport was measured by tracing the linear displacement of the air bubble on top of a millimeter scale. Knowing the volume and the length of the micropipette, the linear movement of the bubble was converted and expressed in µL/hr. [10,11]

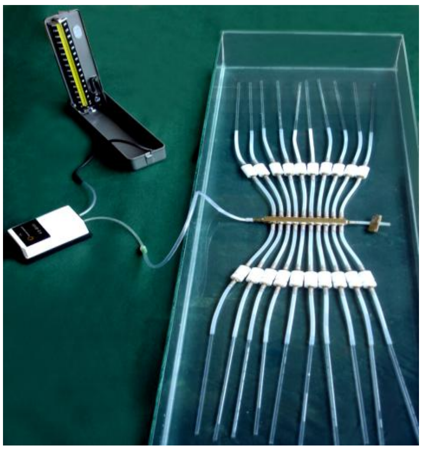

Figure (1): Fluid filtration device assembly.

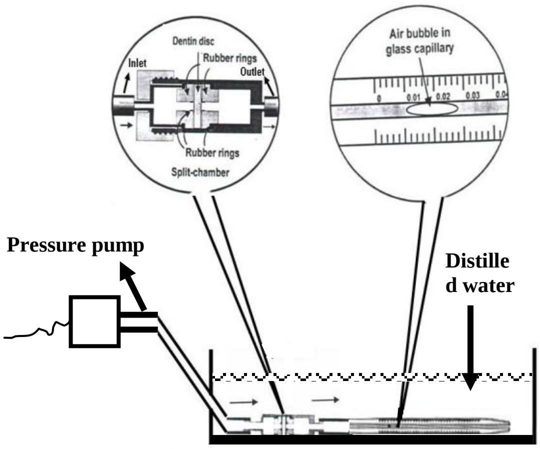

Figure (2): Diagram of fluid transport apparatus assembly.

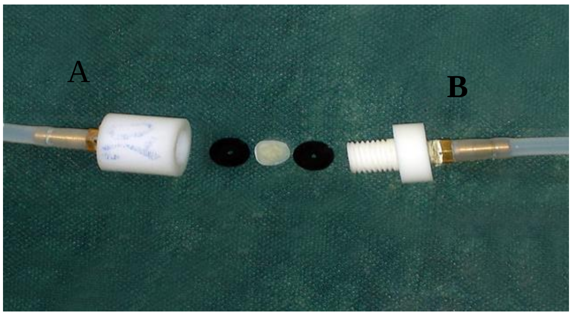

Figure (3): Opened split Teflon chamber device with a pair of rubber "O" rings and a dentin disc.
A: female part, B: male part.

2) Push-out shear bond strength: Each specimen was fixed using self-cured acrylic resin, with its apical aspect (side of smaller diameter) facing up- wards, within a custom made loading fixture. Each specimen was subjected to compressive loading at a crosshead speed of 0.5 mm/min. Load was applied by a cylindrical stainless steel plunger of 0.8 mm diameter, in an apical coronal direction because of the convergence of the root canal sections, to avoid any constriction interference during push-out testing. The plunger was used as a force probe, mounted on the moving upper head of the universal testing machine. Care was taken where the plunger tip was sized and positioned to contact only the root canal filling to displace it downward, without stressing the surrounding dentin. Failure was manifested by extrusion of filling material from the canal. The maximum failure load was recorded in Newtons and converted into MPa.

The bond strength was calculated from the recorded peak load divided by the computed surface area as calculated using the following formula; [12, 13] Shear bond strength = F/A [$A = (\pi h (r^1+r^2)$]
Where,
F: Is the maximum load at failure in N,
π: Is the constant 3.14
r^1: Apical radius
r^2: Coronal one
h: Is the thickness of the sample in millimeters.

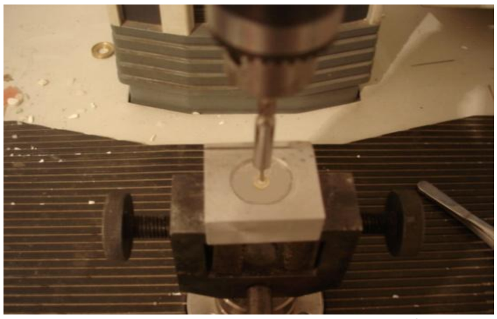

Figure (4): Specimen and attachments used for shear bond strength test.

3) Scanning Electron Microscope (SEM)

A random disc from each group was kept for qualitative evaluation of adhesive interfaces. The specimens were gold sputtered, morphological evaluation of the dentin/sealer interface was conducted using scanning electron microscope, and photographs were taken at different magnifications.

Statistical analysis

Data management and analysis were performed using Statistical Package for Social Sciences (SPSS) vs. 20. Differences between the two groups were tested using *the Kruskal-Wallis* test, a nonparametric test, equivalent to the analysis of variance (ANOVA) procedure, *Mann-Whitney* which is also a non- parametric test was used to help analyze the specific group pairs for significant differences. P-values $\leq$ 0.001 were considered significant.

RESULTS

1) Sealing Capacity: The mean fluid leakage values of the two investigated materials are listed in table (1). *Kruskal-Wallis and Mann-Whitney* tests showed that there was a statistically significant difference between the two groups ($p < 0.01$). The data indicates that the mean fluid leakage value of the silicone- based sealer (Group 2) was ($0.0963 \mu L^{-1}$). This was followed by the resin- based sealer (Group 1)($0.1813 \mu L^{-1}$), that showed higher mean fluid leakage values.

2) Push-out shear bond strength: As can be seen from table (2), *Kruskal-Wallis* test and *Mann- Whitney* test, showed that there was a statistically significant difference between the two Groups ($p < 0.01$). The resin based sealer (Group 1) exhibited higher statistically significant mean shear bond strength (6.54 MPa), than silicone based sealer (Group 2) (2.89 MPa).

3) Results of SEM evaluation

The morphology of dentin/sealer interface of the two tested materials using a scanning electron microscope was shown in Figures (5) & (6). Figure (5) for the scanning electron micrograph (X 500) of the interface at dentin/silicone based sealer, one can notice the presence of almost gap free space with dispersed needle shaped bundles. On the other hand, Figure (6) is a scanning electron micrograph (X500) of the dentin/resin based sealer interface, showing clear loss of marginal integrity.

TABLE (1): The means, standard deviation (SD) values and results of Kruskal-Wallis test and Mann Whitney for comparison between mean fluid leakage in (µL-1) for the two tested groups.

Group / Test	Resin based sealer (Group 1)		Silicone based sealer (Group 2)		P-value
	Mean	SD	Mean	SD	
Fluid Leakage (Sealing Capacity)	0.1813^{b}	±0.034	0.0963^{a}	±0.0269	< 0.01

Means with the same letter within each column are not significantly different at P<0.01.

TABLE (2): The means, standard deviation (SD) values, results of Kruskal-Wallis test for comparison between shear bond strength in (MPa) for the two tested groups.

Group / Test	Resin based sealer (Group 1)		Silicone based sealer (Group 2)		P-value
	Mean	SD	Mean	SD	
Shear Bond Strength	6.54^{a}	±1.64	2.89^{b}	±0.912	< 0.01

Means with the same letter within each column are not significantly different at P<0.01.

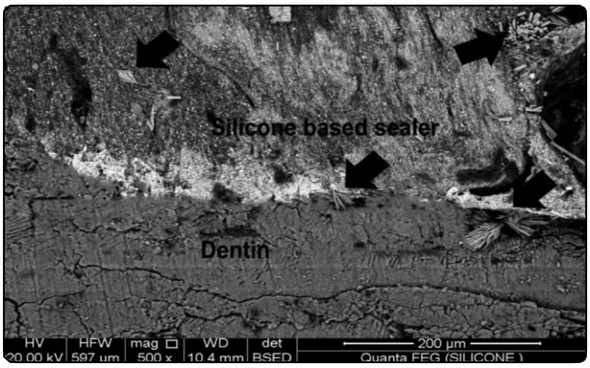

Fig. (5): SEM micrograph at the dentin/silicon based sealer interfaceX500.

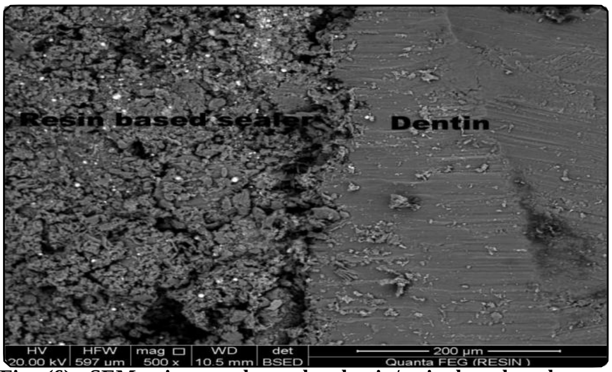

Fig. (6): SEM micrograph at the dentin/resin based sealer interfaceX500.

DISCUSSION

Leakage of the root canal has been defined as a space permitting the passage of bacteria, fluids and chemical substances between the dentinal wall and the root canal filling material, and this result within the sealer itself or at the interface of the filling material and root canal wall. This space can result from deficient adaptation of the filling material to the root dentin, solubility of the sealer or sealer shrinkage. [14]

Sealing failure of sealers may be due to their different chemical compositions and physical properties (adhesiveness, dimensional stability, solubility). In addition, obturation techniques, possible presence of smear layer, accessory canals and irregular canals may be responsible for sealing failure.

The fluid filtration method, in which the sealing capacity measured by means of air bubble movement inside a capillary tube, was used in this study. This method presents many advantages in comparison with dye penetration methods: as the samples are not destroyed therefore, it allows both the apical and coronal sealing to be assessed over the course of time. No tracers are necessary so that, problems related to molecular size and affinity to dentin or pH are avoided. System sensitivity can be adjusted by altering the pressure used or the diameter of the micropipette; it is more sensitive in detecting empty spaces, the fluid transport values provide an indication of both the length and diameter of the void, rather than just the length. [15]

From table (1), it can be generally seen that the sealing ability of the silicone based sealer showed significantly the highest results, followed by the resin based sealer. This may be attributed to the fact that silicone - based sealer/dentin interface revealed an almost homogenous gap free junction, free of voids or cracks within the bulk of the sealer together with accepted adaptation into the dentinal walls (Figure 5). It exhibits some sort of hydrophilicity without tendency to any solubility, it performs pre and post-setting expansion accompanied by low film thickness and a very high flow ability of the material. [16] This initial expansion in the silicone based sealers may explain the better sealing ability provided by these materials. It has been emphasized that even if there is no chemical bond between sealer and dentin, the special new sealer plugs, may have been penetrated into dentinal tubules providing mechanical interlocking which may enhance the sealing ability of the obturation. [15]

Meanwhile, the resin based sealer showed lower sealing ability. Any polymeric endodontic sealer will be subjected to large polymerization stresses during setting that may cause debonding and gap formation along the periphery of the root filling. The highly unfavorable cavity configuration factor (C-factor) inside the root canal has suggested as the main reason for this suboptimal performance. [17] Additional stresses resulting from the relatively fast setting time of resin- based sealer might cause earlier debonding from dentinal walls. Moreover, one can speculate that oil based materials such as resin based sealer could prevent complete wetting of the root canal wall and this may result in poor adaptation of the material especially in areas where remnants of smear layer existed. However, even when shrinkage is prevented as contraction is guided towards the canal walls, contractile forces are produced in the material itself which place a strain on the restored tooth and endanger the internal coherence and increase porosity, creating open spaces.

It is possibly that the resin matrix material preferentially penetrated the dentinal tubules, leaving a sealer layer that is enriched with these large filler particles that are larger than the dentinal tubules diameter. If the sealer layer does not have sufficient bulk or thickness, the loss of resin into the dentinal tubules may not be compensated for, thus it loses the holding of the sealer together and loses its coherence. [18-20] Figure (6) showed a scanning electron micrograph of the loss of integrity at dentin/resin based sealer interface. These gaps, presumably created by polymerization contraction forces, it was suggested that hybrid layer and long tags do not guarantee the absence of gaps.

In Push out shear bond strength, it was expected that the material with better sealing ability would offer better bond strength results, but surprisingly this was not the case. Statistical results in table (2) revealed that resin based had higher bond strength than silicone based sealers. These results may be due to the fact that epoxy resin based sealers are thought to be able to react with any exposed amino groups in collagen presented in the dentinal tubules to form strong chemical covalent bonds during setting reaction. [20-22] These materials are capable of forming a hybrid layer and penetrating deep into dentinal tubules by virtue of their hydrophilic nature in association with pressure caused by condensation technique allowed the sealer to infiltrate into dentinal tubules, forming long tags and secondary branching (Figure 6). [23] Silicone based sealer showed lower bond strength to dentin than resin based one and this may be due to the little opportunity for hydrophobic polydimethylsiloxane to react with dentin resulting in a mechanical bonding rather than a chemical one (Figure 5). [24] Their high flow in combination with their setting expansion improves their mechanical interlocking. [25]

CONCLUSION

Based on the results of this study, it can be concluded that:

1. The compositional pattern of the tested root canal sealing materials and its dimensional changes affect dramatically their physico-mechanical behavior.
2. Improved bonding of sealers to dentin does not necessarily mean the improvement of sealing ability.

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