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Assessing fracture resistance of endodontically treated teeth obturated with four different root canal sealers: An in-vitro study

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***Abstract*---**Background: This study aims to evaluate fracture resistance on endodontically treated teeth when four unique sealers are being used. Materials and Methods: 75 human premolars (mandibular) recently extracted were utilised for this analysis. Random categorization of selected samples into 5 different groups depending on the type of sealer applied in the canal. Group 1: RCTpex

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sealer, Group 2: MTA Fillapex sealer, Group 3: Seal-Pex sealer, Group 4: Traditional zinc oxide-eugenol sealer, Group 5: Control (un-obturated tooth). Universal testing equipment (IIT, Kanpur) was used to assess fracture force after the teeth were inserted in acrylic cubes. Statistical analysis used one way ANOVA and test of post-hoc. All the groups had significant findings ($P < 0.05$) statistically. Results: Groups one and two presented more excellent fracture endurance as compared to other groups. Furthermore, there was no noteworthy difference between group three and four or group four and five statistically. Conclusion: The group of resin sealer was found to be more successful than other groups in this in vitro study. The ZOE sealer group and the control group, however, showed no significant differences.

***Keywords*---**intra-canal sealer, fracture resistance, MTA based sealer, resin-based sealer.

Introduction

The remnant tooth structure following canal preparation governs the prognosis of root canal treated teeth. Over instrumentation, dentine dehydration following endodontic treatment, and uncontrolled pressure application while obturation are all variables that contribute to root fracture after endodontic therapy. Furthermore, the synergistic effects of root canal irrigants and medicaments alters the physio- mechanical features of the root dentin, causing root canal therapy treated teeth to fail or fracture.[1] The intra - canal system is strengthened in endodontically treated teeth by obturation which boosts the tooth's strength to compressive strength. [1]To maintain the impervious nature of the seal, the sealer must be bonded to the dentine. [2] Therefore, a root canal sealer that defends the tooth from fracture of the root would be more valuable. Different research approaches have generated materials that facilitate adhesion, as adhesion and mechanical interlocking are believed to strengthen the residual tooth against fracture.

The zinc oxide eugenol (ZOE) based sealer is the most often used root canal sealer. It has been utilized for decades due to its good physicochemical nature. [3] Nonetheless, post-treatment complications include root canal leakage and recontamination due to eugenol/zinc oxide loss because of their dissolution. [4,5] Waldent RCTpex (Waldent Chemicals) is an intra-canal sealer based on $Ca(OH)_2$. It possesses antibacterial qualities, promotes healing by encouraging the formation of hard tissue, and facilitates the degradation of microbial lipopolysaccharides, preventing reactive root resorption.[6]. Intra-canal sealers based on $Ca(OH)_2$ have good apical sealing and calcified tissue formation at the apical foramen. This sealer's medicinal properties are dependent on its ionized state, which must be somewhat soluble. [7,8]

Waldent Seal-Pex (Waldent Chemicals) is a resin-based intra-canal sealer which is easy to use, has improved wettability for dentine and gutta-percha surfaces and acts as a better sealant. Resin-based intra-canal sealers are favored because they can establish monoblocks between the intra-canal filling and the intra-radicular dentine, and also because of their ability to infiltrate into dentinal tubules. MTA Fillapex (Brazil) is an intra-canal sealer based on mineral trioxide aggregate (MTA). It contains 13 per cent MTA and salicylate resin as they are antibacterial and biocompatible. [9] It possesses properties like increased radiopacity, decreased solubility, decreased expansion during setting, cementum reformation and good sealing action. [10,11] MTA Fillapex creates unbound calcium ions (Ca^{2+})that aid in tissue regeneration and the healing process. [12]

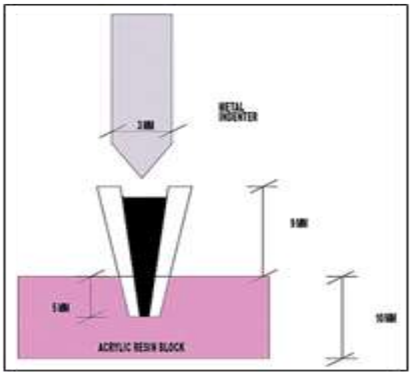
Resin based sealer (Seal-Pex) has shown good root dentin retention, resulting in a good root seal. MTA Fillapex sealer and RCTpex (Calcium-hydroxide based sealer) are both biocompatible and antimicrobial. An intra-canal sealer with antibacterial qualities, the ability to deposit calcified tissue, the creation of a better hermetic seal and root fracture resistance properties is suitable. This study aims to determine the resistance to fracture of root canal sealers of various formulations that were placed in the root dentine of endodontically treated teeth and tested in a universal testing machine.

Materials and Methods

The research was carried out at Rama Dental College, Hospital and Research Centre in Kanpur, Uttar Pradesh, India, in the Department of Conservative Dentistry and Endodontics. 75 healthy, human non-carious premolars of mandible excised for orthodontic procedures were used in this investigation. The selected teeth were carefully washed and preserved in normal saline until the study's conclusion. The fracture resistance test was performed at IIT Kanpur by a universal testing machine by an operator. A wheel diamond bur was used to decoronate the teeth to a 14mm length. Biomechanical preparation was carried out till F3 utilizing a Waldent Premium Taper Gold rotary system (Waldent) with a torque of 3.0 Ncm and 300 rpm speed. Irrigation of canals was done in three phases, starting with 5 ml of 3 percent sodium-hypochlorite, then 17 percent 5 ml of EDTA, and finally normal saline of 5ml. Paper points were used to dry the canals. Obturation is done with gutta-percha points while using the lateral compaction technique. According to the intra-canal sealer utilized, the selected teeth were categorized randomly into five test groups of fifteen teeth in each as follows. (Gutta-percha points were present with sealer in every group)

- Group 1: Waldent Seal-Pex (Waldent Chemicals)
- Group 2: MTA Fillapex
- Group 3: Waldent RCTpex (Waldent Chemicals)
- Group 4: ZOE in a thinner formulation
- Group 5: Control (un-obturated tooth).

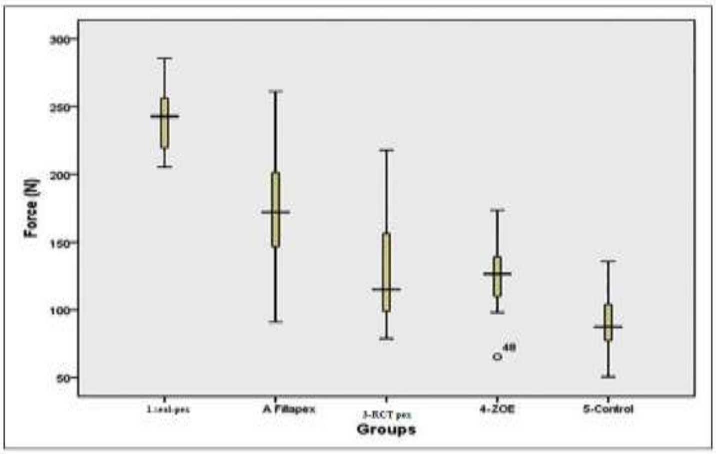
Temporary cement was used to seal the access cavity. At the time of testing, the apical 5 mm of root was placed in acrylic and the 9mm root length was exposed for vertical orientation. For two weeks, all of the samples were kept at 98.6F and relative humidity of 100 percent. A universal testing machine was used to assess fracture resistance at IIT Kanpur in India. The roots vertically aligned in acrylic blocks were installed one after the other on the testing machine’s lower platform. A three-mm-diameter metal indenter tightened on the upper jig was used to apply force vertically along the root's long axis. The metal indenter's tip was positioned on the orifice of the canal. At 1mm/min crosshead speed, every sample was exposed to ascending force applied vertically till the root cracked. At zero degree angulation, the compressive load was directed to the root's long axis. The test was stopped when the applied load decreased and the root cracking sound was heard [1st Figure]. The force applied in newtons necessary for root fracture was measured. The information was gathered and analyzed using a one way ANOVA and test of post-hoc. For statistical analysis, SPSS software version 2.0 was used and the significance level was set at $P \geq 0.05$.



1st Figure: For the load to fracture test, a pictorial representation of the root segment is shown. The root of 5 mm length was vertically placed in an acrylic block of 10mm dimension along with a 9 mm coronal part exposed. A diameter metal indenter of 3mm with 1 mm/min crosshead speed is utilized to measure the fracture resistance of endodontically treated teeth.

Results

The Shapiro–Wilk test was used to determine the normality of the data in this study, and it was observed to be normalized ($P \geq 0.05$) [2nd Figure]



[2nd Figure]: The distinct groups denoting the pattern of recorded fracture force distribution through a box plot diagram. (n: Newton)

Fracture forces of different groups

The mean ± standard deviation of fracture force in respective groups are as follows:

- Group 1 (Waldent Seal-Pex) = 240.74 ±23.88 N
- Group 2 (MTA Fillapex) = 174.53 ±48.06 N
- Group 3 (Waldent RCTpex) = 128.59 ± 41.35 N
- Group 4 (ZOE) = 125.54 ±26.78 N
- Group 5 (Control) = 89.83 ±25.72 N.

The largest fracture force of 240.74 ±23.88 N seen in Group I (Waldent Seal-Pex), whereas the lowest fracture force of 89.83 ±25.72 N was seen in Group V (Control) [Figure 3].

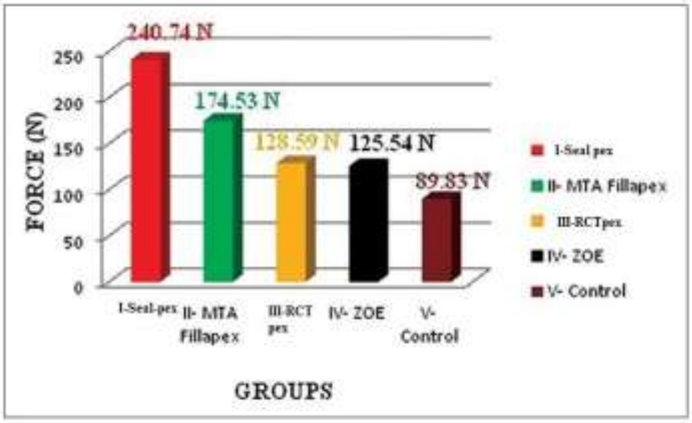


Figure 3: All the five groups showing mean values of fracture force (n: Newton)

One-way ANOVA and post hoc (Tukey test) were used to compare groups

When post-hoc analysis was implemented, the significance level was kept at 0.05, Group 1(Waldent Seal-Pex) demonstrated significant differences statistically when compared to the other four groups. While comparing Group 3 (Waldent RCTpex) and Group 4 (ZOE) with Group 2 (MTA Fillapex), Group-2 demonstrated a significant difference statistically. While comparing Group 4 (ZOE) and Group 3 (Waldent RCTpex), Group 3 exhibited no significant difference statistically. Furthermore, when comparing the two groups, Group 4 (ZOE) and Group 5 (Control) no significant difference was noted statistically [1st Table].

1st Table: Shows the fracture force comparisons amongst the various groups.

Group	Fracture force (newton) HSD (Tukey's test)				
	Mean difference	SE	Significant	95% CI	
				Lower bound	Upper bound
I versus II	66.21	12.61	0.000**	29.66	102.77
I versus III	112.15	12.61	0.000**	75.59	148.71

I versus IV	115.20	12.61	0.000**	78.65	151.76
I versus V	150.91	12.61	0.000**	114.36	187.47
II versus III	45.93	12.61	0.005*	9.38	82.49
II versus IV	48.99	12.61	0.002*	12.43	85.54
II versus V	84.70	12.61	0.000**	48.14	121.25
III versus IV	3.05	12.61	1.000 (NS)	−33.50	39.60
III versus V	38.76	12.61	0.030*	2.20	75.31
IV versus V	35.71	12.61	0.060 (NS)	−0.84	72.26

The mean difference is significant at the 0.05 level. **Highly significant (P<0.001), *Significant (P<0.05). NS: Not significant (P>0.05); CI: Confidence interval; SE: Standard error; HSD: Honestly significant difference.

Discussion

A sealer is a component that connects the radicular dentin to the intra-canal filling material. While the creation of core/post spaces in the canal's coronal and middle thirds, and when intra-oral flexural forces are acting, the capability of a sealer to resist breakage in the seal created by micro-mechanical retention is of great importance.[14] The sealer's goal is to hide imperfections that Gutta-percha can't cover, like lateral depressions and grooves[15], and lateral canals[17]. They increase adaptation marginally with the dentinal walls[16]. Microleakage and bacterial contamination should be avoided. [18] Adhesion between sealer and radicular dentin is crucial for two reasons. Firstly , the coronal and apical leakage is decreased by the achieved seal[19] and secondly, it prevents filler material displacement during restorative treatments. [20] Zinc oxide eugenol sealer, calcium hydroxide sealer, glass ionomer sealer, resin sealers (epoxy based, UDMA-based), recent advances like Bio-ceramic and MTA based sealers have all been employed over the years.

To be optimal, a sealer must have excellent fracture resistance and the ability to construct an effective monoblock with the obturating substance. As a result, sealer fracture resistance must be evaluated. So, this study was conducted to assess the fracture resistance of roots filled with various intra-canal sealer materials with the help of the universal examining apparatus. Sedgley and Messer utilized vertical load to assess the friability of endodontically treated teeth, and the same technique was used here as well. [21] In this research, the delivered force was angled at 0 degrees, which created splitting stress that acted directly on the access preparation. Because bending movements were minimized and maximum loads were situated more cervically, lower stresses were generated. This study was clinically more relevant because it well mimics the sustenance provided by alveolar bone to healthy teeth, resulting in fewer fatal stress build-ups induced via unnatural flexible movements[22]. The fracture was discovered to be parallel to the bonding surface of the dentin.

The findings of this investigation revealed that Seal-Pex (P <0.001) had much higher fracture resistance than compared to other sealers evaluated. These findings are consistent with Fisher et al's research, which demonstrated resin-based sealers had a significantly (P<0.05) higher bond strength than all other groups. Seal-Pex has a better fracture resistance since an open epoxide ring forms a covalent link with any exposed amino groups in the collagen. With its gliding property and lengthy polymerization period, Seal-Pex penetrates micro-irregularities better and increases the bond mechanically between the sealer and dentin of the root. [24] The binding strength of the resin-based intra-canal sealer to dentin and obturating material was higher than the Zinc-oxide eugenol based and calcium hydroxide based sealer.

Nagas et al.[26] linked resin-based sealer's strong fracture resistance with its minimal setting shrinkage and better stability. It's tough, and when combined with gutta-percha, it makes a great seal with walls of dentin, providing greater strength and fracture resistance. In their investigation, McMichen et al.[8] discovered that resin sealers are lower soluble in nature and larger film thickness compared to other sealers, which could explain their superior bond strength. [8] MTA based sealer demonstrated considerably stronger fracture resistance ($P < 0.05$) than RCTpex, traditional ZOE, and control group in this investigation, but decreased bond-strength as compared to Seal-Pex.

Sarkar et al [27] said that when a set sealer releases calcium and hydroxyl ions, apatite is formed. Reyes-Carmona et al.[28] also demonstrated that MTA and phosphate salts generated apatite gets accumulated within collagen fibers, this results in an increased production of inorganic nucleation on the surface of dentin that behave as a tag-like layer. According to Nagas et al.[26] and Amin et al., the decreased fracture resistance of MTA sealer than Seal-Pex is due to decreased adhesive capacity of the tag-like layer .[29]

Fracture resistance of RCT-pex is lower than Seal-Pex and MTA sealer in this study, which could be a result of its higher soluble nature that eventually causes the seal to break, decreasing the root canal sealer's capacity to seal. McMichen et al.[8] discovered that values of solubility for $Ca(OH)_2$ based sealer were roughly 200 times higher than those for resin-based sealer, implying that there was a significant breakdown. Epoxy resin-based sealers, according to Grossman, have the least weight loss. [30] In this trial, there was no significant difference between RCTpex and standard ZOE statistically. According to Rothier et al[31], Siqueira et al[32] and Limkangwalmongkol et al[33] the physico-chemical features of calcium hydroxide made sealers were intermediate or little greater than that of Zinc-oxide eugenol comprised sealer.

Zinc-oxide eugenol based sealer bonds through a chelation reaction that occurs during the setting process. The zinc ion combines with both the mineral component of dentin and the ZnO contained in the GP(gutta percha) cone, forming a meshwork which improves contact between the above-mentioned materials. [34] According to this investigation, the ZOE sealer had the least resistance to fracture amid all the four sealers. According to Gopikrishna et al research, it has low adhesive and cohesive strength [36] and McComb & Smith [35] found that ZOE sealer has no adhesive features; these two studies are in conjunction with the present study. RCTpex had greater fracture resistance values than ZOE in this investigation, while the differences were not statistically significant this can be because calcium hydroxide based sealers have reduced microleakage than ZOE based sealers according Siqueira et al.[32]

In fracture resistance between the ZOE and control group no substantial difference was noted, which coincides with prior research by Bhat et al [1] and Chadha et al [24]. However, leaving the root canals un-obturated is not recommended. The main intention of endodontic therapy is to obturate the biomechanically prepared root canal with gutta percha & sealers which is done by creating a monoblock with dentin of the root canal. The inter - group comparison between ZOE and the un-obturated (control group) is meaningful only in the laboratory, not in the clinical setting. Seal-Pex has recently gained popularity as a sealer because of its superior adherence to gutta percha. Both MTA-Fillapex and RCTpex are curative sealers with the capacity to mend and renew apical tissues. Our research found that MTA based sealer had a higher bond strength than RCTpex, therefore in some circumstances, MTA Fillapex can be used to create a great hermetic seal. Seal-Pex, on the other side, adheres better than most root canal sealers therefore, should be utilized to promote improved root canal attachment and a better secondary monoblock.

Conclusion

This study's results can be concluded as follows:

- Among the groups, SEAL-PEX (240.74 ± 23.88 N) had the highest fracture resistance values, and then MTA constituted sealer (174.53 ± 48.06 N).
- SEAL-PEX and MTA-Fillapex outperformed the other sealers in terms of push-out bond strength.
- The strongest push-out bond strength was found in SEAL-PEX (240.74 ± 23.88 N), whereas the weakest was found in non-obturated root canals (89.83 ± 25.72 N).

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