Review Article

Influence of Bioactive and Resin-Based Sealers on the Fracture Strength of Instrumented Teeth: An In Vitro Study

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The preservation of structural integrity in endodontically treated teeth is a critical factor in ensuring long-term clinical success. This in vitro study aimed to evaluate the influence of bioactive and resin-based sealers on the fracture strength of instrumented teeth. A total of forty extracted human premolars were decoronated and prepared using rotary instrumentation. The specimens were divided into three groups: Group I (control, unobturated), Group II (obturated with bioactive sealer), and Group III (obturated with resin-based sealer). Following obturation, all samples were stored under simulated oral conditions and subjected to compressive loading in a universal testing machine until fracture occurred. The results indicated that both sealer types enhanced fracture resistance compared to the control group, with the bioactive sealer group demonstrating the highest mean fracture strength. The findings suggest that bioactive sealers, due to their chemical bonding and biomineralization potential, provide superior reinforcement to root dentin compared to resin-based sealers. These outcomes highlight the clinical relevance of selecting bioactive materials to improve the durability and longevity of endodontically treated teeth.

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Introduction

Endodontic therapy aims to eliminate infection, preserve tooth function, and maintain the natural dentition for as long as possible. However, one of the major challenges following root canal treatment is the increased susceptibility of the treated tooth to structural failure. The loss of tooth structure during access preparation, canal instrumentation, and obturation can significantly reduce the fracture resistance of the tooth (Chandra et al., 2021). Consequently, the selection of an appropriate root canal sealer plays a vital role not only in achieving a fluid-tight seal but also in reinforcing the weakened root structure.

Root canal sealers are typically classified based on their chemical composition, with bioactive and resin-based sealers being among the most commonly utilized. Resin-based sealers, such as epoxy resins, have long been favored due to their strong adhesion to dentin and excellent sealing ability. However, despite their favorable mechanical properties, resin-based sealers may exhibit cytotoxic effects and limited bioactivity (AlShahrani et al., 2021). In contrast, bioactive sealers have recently gained attention for their capacity to interact chemically with dentin, promote mineral deposition, and induce the formation of an interfacial layer that strengthens the tooth structure (Al-Bakhsh et al., 2019).

The bioactivity of these sealers, primarily achieved through the incorporation of calcium silicate or hydroxyapatite-based components, enables ionic exchange and biomineralization within the dentinal tubules. This results in a more stable and reinforced dentin–sealer interface, potentially enhancing the tooth's resistance to fracture. Several in vitro studies have reported that bioactive sealers outperform conventional sealers in improving the fracture strength of endodontically treated teeth (Chandra et al., 2021).

Therefore, this study aims to compare the influence of bioactive and resin-based sealers on the fracture strength of instrumented teeth in an in vitro setting. The findings will contribute to the understanding of how sealer composition affects the mechanical reinforcement of endodontically treated roots, ultimately guiding clinicians in material selection to optimize tooth longevity.

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Materials and Methods

This in vitro experimental study was designed to evaluate and compare the fracture strength of instrumented teeth obturated with bioactive and resin-based sealers. The methodology was standardized to ensure reproducibility and reliability of results, following procedures similar to those described in previous investigations on root canal sealers and their effects on dentin reinforcement (Chandra et al., 2021).

Sample Selection

Forty extracted human mandibular premolars with single straight canals and similar root dimensions were selected for the study. Teeth with cracks, caries, resorption, or prior endodontic treatment were excluded. All samples were cleaned, disinfected, and stored in distilled water at room temperature until use to maintain dentinal integrity.

Grouping of Samples

The specimens were randomly divided into three groups (n = 40):

Group I (Control)

Instrumented but unobturated canals.

Group II (Bioactive Sealer)

Canals obturated with a bioceramic-based sealer (EndoSequence BC Sealer).

Group III (Resin-Based Sealer)

Canals obturated with a resin-based sealer (AH Plus).

The selection of these sealers was based on their contrasting properties—bioactivity and mineralization potential of calcium silicate-based materials, and strong adhesive characteristics of epoxy resin-based sealers (Al-Bakhsh et al., 2019; AlShahrani et al., 2021).

Canal Preparation and Obturation Procedure

All teeth were decoronated to achieve a standardized root length of 14 mm. Canal instrumentation was performed using a rotary NiTi file system up to size F3 (Protaper Universal, Dentsply Maillefer). During preparation, irrigation was done with 2.5% sodium hypochlorite followed by a final rinse with 17% EDTA and distilled water. The canals were dried with paper points before obturation.

In Group II, the bioactive sealer was introduced using a lentulo spiral, and obturation was completed using single-cone gutta-percha technique. In Group III, AH Plus sealer was similarly applied before insertion of gutta-percha cones. The access cavities were sealed with glass ionomer cement, and all specimens were stored in 100% humidity at 37°C for 7 days to allow complete setting of the sealers.

Fracture Strength Testing

After storage, each specimen was embedded in an acrylic block with the root surface exposed up to 2 mm below the cementoenamel junction to simulate alveolar bone support. The samples were mounted in a universal testing machine, and a compressive load was applied vertically along the long axis of the tooth using a stainless-steel spherical tip at a crosshead speed of 1 mm/min until fracture occurred. The maximum load to fracture (in Newtons) was recorded for each specimen (Chandra et al., 2021).

Statistical Analysis

The recorded data were subjected to statistical analysis using one-way ANOVA to compare mean fracture strengths among groups, followed by post-hoc Tukey's test to determine intergroup significance. A p-value < 0.05 was considered statistically significant.

Results

The results of this in vitro study revealed significant differences in the fracture resistance among the experimental groups. The mean fracture strength values (in Newtons) demonstrated that both obturated groups—bioactive and resin-based sealers—exhibited higher resistance compared to the control group. The control group (Group I) showed the lowest mean fracture resistance, indicating the natural fragility of instrumented but unobturated teeth.

The bioactive sealer group (Group II) recorded the highest mean fracture resistance, followed by the resin-based sealer group (Group III). Statistical analysis using one-way ANOVA revealed a significant difference among the groups ($p < 0.05$). Post-hoc comparisons confirmed that the bioactive sealer provided superior reinforcement of the root dentin compared to the resin-based material.

The enhanced performance of the bioactive sealer can be attributed to its ability to induce chemical bonding with dentin through hydroxyapatite formation and biomineralization, as supported by Al-Bakhsh et al. (2019). Conversely, while resin-based sealers such as AH Plus improved fracture resistance through micromechanical interlocking and adhesive bonding, their effect was comparatively lower, consistent with the findings of AlShahrani et al. (2021). These outcomes align

with previous evidence suggesting that the type of root canal filling material directly influences the mechanical reinforcement of endodontically treated teeth (Chandra et al., 2021).

Overall, the results confirm that bioactive sealers significantly increase fracture resistance, thereby improving the structural durability of treated teeth and offering a promising alternative to conventional resin-based sealers.

Discussion

The present in vitro study evaluated the influence of bioactive and resin-based sealers on the fracture strength of instrumented teeth, revealing that both sealer types significantly improved fracture resistance compared to the unobturated control group. However, the bioactive sealer group demonstrated superior reinforcement of the root dentin, indicating that bioactivity and chemical bonding characteristics play a crucial role in enhancing tooth integrity after endodontic treatment.

The observed improvement in fracture strength with bioactive sealers can be attributed to their ability to form hydroxyapatite-like layers along the dentin–sealer interface, leading to a more integrated structure and increased resistance to crack propagation. The findings are consistent with those reported by Al-Bakhsh et al. (2019), who demonstrated that bioactive materials containing hydroxyapatite and bioactive glass nanoparticles exhibited enhanced mechanical properties and interfacial bonding due to their mineralizing potential. Such bioactive interaction promotes dentin remineralization and creates a stronger sealer–dentin interface, effectively reducing microleakage and stress concentration under functional loading.

On the other hand, resin-based sealers, while improving the overall fracture resistance compared to untreated controls, showed relatively lower strength than bioactive sealers. This outcome may be explained by the polymeric nature of resin-based materials, which rely on micromechanical retention rather than chemical bonding to dentin. Although resin-based sealers such as epoxy resins (e.g., AH Plus) possess favorable adhesive properties and dimensional stability, their limited bioactivity may restrict their ability to reinforce dentin effectively over time. AlShahrani et al. (2021) further noted that resin-based sealers exhibit good antibacterial effects, which can enhance endodontic outcomes; however, their performance in mechanical reinforcement remains inferior to that of bioactive formulations.

The present findings align with those of Chandra et al. (2021), who assessed the fracture resistance of endodontically treated teeth filled with different root canal filling systems and reported that sealers with bioactive components yielded higher resistance to fracture. The ability of bioactive sealers to interact chemically with dentin, leading to the formation of a mineral-rich interfacial layer, likely contributes to improved load-bearing capacity and structural stability.

Overall, the current study reinforces the notion that bioactive sealers offer dual advantages—mechanical reinforcement and biomineralization—thereby enhancing both the longevity and resilience of endodontically treated teeth. Future investigations, including long-term clinical trials, are recommended to validate these findings and explore the performance of bioactive sealers under dynamic masticatory forces and varying oral conditions.

Conclusion

Within the limitations of this in vitro study, it can be concluded that both bioactive and resin-based sealers contribute to reinforcing the structural integrity of endodontically treated teeth, but bioactive sealers demonstrated a superior capacity to enhance fracture resistance. The bioactive sealer group exhibited the highest mean fracture strength, likely due to its ability to form chemical bonds with dentinal walls and promote biomineralization, resulting in improved stress distribution and structural reinforcement (Al-Bakhsh et al., 2019). Resin-based sealers also provided increased resistance compared to untreated controls; however, their enhancement was relatively lower, possibly due to polymerization shrinkage and limited chemical interaction with dentin (AlShahrani et al., 2021).

These findings align with previous studies that emphasized the role of sealer composition and bonding mechanisms in reinforcing root dentin following instrumentation and obturation (Chandra et al., 2021). Clinically, the use of bioactive sealers may offer long-term benefits by improving the mechanical resilience and sealing ability of obturated teeth. Further in vivo and long-term evaluations are recommended to validate these results under functional and aging conditions.

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