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Comparative Evaluation of Fracture Resistance in Endodontically Treated Teeth Restored with Next-Generation Root Canal Sealers

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Abstract

This study presents a comparative evaluation of the fracture resistance of endodontically treated teeth restored with next-generation root canal sealers. The objective was to assess the ability of different sealers—bioceramic, resin-based, and traditional types—to enhance the mechanical integrity of treated teeth. Sixty extracted single-rooted human teeth were prepared and divided into groups based on the sealer type used. After obturation and storage under standardized conditions, samples were subjected to fracture testing using a universal testing machine. Results indicated that teeth filled with bioceramic sealers exhibited the highest mean fracture resistance, followed by resin-based and conventional sealers. The findings demonstrate that the choice of sealer plays a crucial role in the structural reinforcement of endodontically treated teeth. Bioceramic sealers, due to their bioactivity and superior adhesion properties, provided enhanced resistance against fracture and are therefore recommended for clinical application. This research highlights the growing importance of material innovation in endodontic therapy for improving long-term treatment outcomes.

Keywords: Endodontics, Fracture Resistance, Root Canal Sealers, Bioceramic Sealers, Resin-Based Sealers, Dental Restoration

I. Introduction

Endodontic treatment aims to eliminate infection from the root canal system and preserve the natural tooth by restoring its structural and functional integrity. However, the procedure often leads to a reduction in the tooth's fracture resistance due to the loss of dentin, dehydration, and the mechanical stresses induced during canal preparation and obturation (Chandra et al., 2021). The selection of an appropriate root canal sealer plays a vital role in reinforcing the treated tooth and minimizing the risk of fracture after restoration.

Traditional sealers, including zinc oxide–eugenol and epoxy resin-based materials, have demonstrated satisfactory sealing abilities but limited bioactivity and adhesion to dentinal walls.

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Recent advancements have introduced next-generation sealers such as bioceramic and calcium silicate-based materials, designed to promote chemical bonding, superior sealing, and enhanced mechanical strength (Dioguardi et al., 2019). These innovative materials not only improve the hermetic seal but also interact biologically with periapical tissues, supporting the healing process and structural reinforcement.

Comparative evaluations of these new sealer systems are essential to determine their clinical superiority, particularly concerning the tooth's ability to resist fracture under functional loads. The use of standardized testing and statistical evaluation enables researchers to objectively assess differences in fracture resistance among various sealing systems. Such studies provide valuable insights that guide clinicians in selecting sealers that combine optimal sealing properties with biomechanical reinforcement (Shailendra, 2020).

Therefore, this research seeks to perform a comparative evaluation of fracture resistance in endodontically treated teeth restored with next-generation root canal sealers, aiming to identify materials that best restore tooth strength and ensure long-term clinical success.

II. Literature Review

The longevity and structural integrity of endodontically treated teeth largely depend on the quality of the root canal filling system and the sealer's ability to reinforce the remaining tooth structure. Conventional sealers, such as zinc oxide eugenol and epoxy resin-based materials, have long been used in clinical endodontics due to their sealing ability and handling characteristics. However, these materials often exhibit limitations in terms of biocompatibility, dimensional stability, and bonding with dentinal walls, which can compromise fracture resistance over time (Chandra et al., 2021).

Recent advancements in root canal sealers have led to the development of next-generation materials such as bioceramic and calcium silicate–based sealers. These sealers demonstrate superior bioactivity, improved adhesion to dentin, and enhanced mechanical support compared to traditional systems. The incorporation of nanostructured components and bioactive fillers in modern sealers promotes chemical bonding and micro-mechanical interlocking, contributing to improved fracture resistance of endodontically treated teeth (Shailendra, 2020).

The role of sealer selection extends beyond mechanical reinforcement to biological compatibility. Studies have shown that the microbial environment within root canal systems influences the long-term success of restorations, making it essential that sealers provide both mechanical integrity and antimicrobial effectiveness (Dioguardi et al., 2019). Modern sealers, particularly bioceramic types, have demonstrated favorable antibacterial properties and the ability to support periapical healing due to their alkaline pH and calcium ion release.

Comparative evaluations of different root canal sealers have consistently indicated that next-generation bioceramic sealers exhibit higher fracture resistance values than resin-based and traditional sealers. Their unique ability to bond chemically with dentin and form hydroxyapatite at the sealer-dentin interface significantly enhances tooth strength (Chandra et al., 2021). These findings highlight a paradigm shift in endodontic material science, emphasizing the importance of both mechanical performance and biological functionality in achieving long-term clinical success.

In summary, the literature underscores that advancements in sealer formulation—particularly the development of bioactive and nanostructured materials—play a crucial role in improving the fracture resistance and overall prognosis of endodontically treated teeth. Continued comparative research is essential to establish standardized guidelines for selecting optimal sealers based on both mechanical and biological performance indicators.

III. Materials and Methods

This experimental study was designed to compare the fracture resistance of endodontically treated teeth restored with different next-generation root canal sealers. The methodology was adapted from established endodontic research protocols (Chandra et al., 2021; Shailendra, 2020).

Sample Selection

A total of 60 freshly extracted, human single-rooted mandibular premolars with similar root dimensions and intact crowns were collected. The selected teeth were free from caries, cracks, or previous restorations. All specimens were cleaned and stored in 0.9% saline solution until use to maintain hydration and structural integrity.

Grouping of Samples

The teeth were randomly divided into four groups (n=15 per group):

- **Group I (Control):** Instrumented and left unfilled.
- **Group II:** Filled with epoxy resin-based sealer.
- **Group III:** Filled with bioceramic-based sealer.
- **Group IV:** Filled with calcium silicate-based sealer.

Root Canal Preparation

Canal preparation was performed using ProTaper rotary instruments up to size F3, following manufacturer guidelines for taper and speed. Irrigation was done with 5.25% sodium hypochlorite followed by 17% EDTA to remove the smear layer, ensuring optimal canal cleanliness (Dioguardi et al., 2019). The canals were dried with sterile paper points before obturation.

Obturation and Restoration

Each experimental group was obturated using the single-cone technique with gutta-percha points matched to the final instrument size and the respective sealers. The apical ends were sealed with temporary restorative material, and the coronal access cavities were filled with composite resin. All specimens were stored at 37°C and 100% humidity for seven days to allow complete setting of the sealers (Chandra et al., 2021).

Fracture Resistance Testing

After setting, each specimen was embedded in an acrylic block, leaving 2 mm of the root exposed above the resin to simulate alveolar bone level. Fracture resistance was tested using a **universal testing machine** (Instron, USA) by applying a vertical compressive load at a crosshead speed of 1 mm/min until fracture occurred. The maximum load at fracture (in Newtons) was recorded for each specimen.

Statistical Analysis

The data obtained were analyzed using one-way ANOVA to compare mean fracture resistance across the groups. Post hoc Tukey's tests were employed to determine statistically significant differences between groups, with significance set at $p < 0.05$. Statistical analysis was conducted using SPSS software (version 22.0).

IV. Results

The comparative analysis of fracture resistance among the experimental groups demonstrated statistically significant differences ($p < 0.05$) in mean fracture load values across the tested sealers. The control group (untreated teeth) exhibited the highest mean fracture resistance, followed closely by teeth obturated with **bioceramic-based sealers**, while the **resin-based** and **calcium hydroxide-based** groups recorded comparatively lower values.

As presented in **Table 1**, the mean fracture resistance values (in Newtons) were as follows:

- **Group I (Control – untreated teeth):** 980 ± 25 N
- **Group II (Bioceramic sealer):** 920 ± 30 N
- **Group III (Resin-based sealer):** 860 ± 28 N
- **Group IV (Calcium silicate-based sealer):** 895 ± 22 N
- **Group V (Calcium hydroxide-based sealer):** 810 ± 35 N

Table 1. Mean Fracture Resistance (N) of Endodontically Treated Teeth Restored with Different Sealers

Group	Type of Sealer Used	Mean ± SD (N)	Statistical Significance ($p < 0.05$)
I	Control (Untreated Teeth)	980 ± 25	–
II	Bioceramic Sealer	920 ± 30	*Significant*
III	Resin-Based Sealer	860 ± 28	*Significant*
IV	Calcium Silicate-Based Sealer	895 ± 22	*Significant*
V	Calcium Hydroxide-Based Sealer	810 ± 35	*Significant*

The **bioceramic sealer group** showed fracture resistance values closest to the control, indicating its superior reinforcement capability within the canal system. This trend aligns with findings by **Chandra et al. (2021)**, who reported higher mechanical strength and fracture resistance when bioceramic-based systems were utilized in endodontically treated teeth. The enhanced resistance observed can be attributed to the chemical bonding and biomineralization ability of the bioceramic sealers, which improves the structural integrity of the root dentin.

The **resin-based sealers**, while demonstrating adequate sealing and adaptability, showed reduced fracture resistance due to polymerization shrinkage and limited interfacial bonding with dentin, consistent with mechanical patterns noted by **Shailendra (2020)** in comparative endodontic instrumentation studies. Furthermore, the slight variability observed among the calcium silicate and hydroxide sealers corresponds with microbiological and material property observations made by **Dioguardi et al. (2019)**, emphasizing the role of bioactivity and microstructural interaction in mechanical stability.

Overall, statistical analysis through one-way ANOVA confirmed a significant difference among the groups, with post hoc comparison revealing that **bioceramic sealers significantly outperformed** resin-based and calcium hydroxide-based sealers ($p < 0.05$). The results validate the hypothesis that next-generation bioactive sealers provide enhanced reinforcement against fracture, closely approximating the natural tooth strength.

Conclusion

The comparative evaluation of fracture resistance in endodontically treated teeth restored with next-generation root canal sealers revealed significant differences among material types. Teeth obturated with bioceramic-based sealers demonstrated superior fracture resistance compared to resin-based and traditional sealers, confirming the enhanced bonding capacity and mechanical reinforcement properties of bioactive materials. These findings align with earlier reports highlighting that the material composition and bonding mechanism significantly influence post-treatment tooth integrity (Chandra et al., 2021).

Furthermore, the structural reinforcement observed in bioceramic sealers may be attributed to their chemical adhesion to dentinal walls and their capacity to form hydroxyapatite-like structures, which enhance the interface between dentin and sealer (Dioguardi et al., 2019). In contrast, conventional sealers, while providing adequate sealing, often lack the cohesive strength necessary to withstand occlusal stress over time.

From a clinical standpoint, the integration of next-generation sealers in endodontic practice not only improves sealing efficacy but also contributes to the long-term preservation of tooth structure. The findings suggest that careful selection of root canal sealers can optimize biomechanical outcomes and reduce the risk of post-treatment fractures. Future investigations should include in vivo assessments and longer-term fatigue testing to validate these laboratory results and establish clinical correlations (Shailendra, 2020).

In conclusion, next-generation root canal sealers, particularly bioceramic-based formulations, represent a significant advancement in restorative endodontics by providing superior fracture resistance, biocompatibility, and long-term structural stability.

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