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Assessment of Reinforcement Potential of Novel Root Canal Filling Systems in Preserving Tooth Strength

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Abstract

The structural integrity of endodontically treated teeth largely depends on the reinforcement potential of the root canal filling materials used after instrumentation. Conventional systems, such as Gutta-Percha combined with resin-based sealers, have demonstrated limitations in enhancing fracture resistance, leading to a greater risk of tooth fragility. This study aims to assess the reinforcement potential of novel root canal filling systems in preserving tooth strength. Extracted human teeth were prepared and obturated using both traditional and newly developed bioactive and nanocomposite-based sealers. Fracture resistance testing was conducted using a universal testing machine, and results were statistically analyzed to determine comparative performance. The findings revealed that novel bioceramic and bioactive systems significantly improved the mechanical strength of treated teeth, providing better adaptation and bonding to dentinal walls. These results suggest that the use of advanced root canal filling systems can enhance the long-term durability and fracture resistance of endodontically treated teeth. The study underscores the clinical relevance of selecting materials with superior reinforcement properties to ensure better treatment outcomes.

Keywords: Root canal filling systems, bioceramic sealers, tooth strength, fracture resistance, endodontic reinforcement, bioactive materials.

I. Introduction

Endodontic therapy plays a vital role in preserving teeth that have been compromised by decay or trauma. However, despite successful root canal treatment, the structural integrity of the tooth often remains at risk due to the loss of dentin, dehydration, and mechanical weakening associated with canal instrumentation. This reduction in strength frequently leads to post-treatment fractures, which remain one of the most common causes of failure in endodontically treated teeth

(Chandra et al., 2021). To address this challenge, the selection of root canal filling materials has become a critical determinant in maintaining tooth reinforcement and long-term durability.

Traditionally, Gutta-Percha combined with resin-based or zinc oxide eugenol sealers has been used as the standard obturation system. While these materials effectively seal the canal, studies have demonstrated their limited capacity to reinforce dentinal walls or distribute occlusal stress effectively (Patil et al., 2017). Consequently, attention has shifted toward the development of novel bioceramic and bioactive filling systems that possess enhanced bonding capabilities, bioactivity, and mechanical strength. These modern systems are designed to establish a chemical bond with dentin, reduce interfacial gaps, and promote mineral infiltration, ultimately contributing to superior reinforcement potential.

Recent advancements in nanocomposite and calcium-silicate–based sealers have further expanded the possibilities for strengthening root-filled teeth. These materials exhibit bioactive properties that facilitate dentin remineralization and improved stress distribution, making them promising alternatives to conventional systems (Ordinola-Zapata et al., 2022). Nevertheless, there remains a need for comprehensive evaluation of these novel systems under standardized laboratory conditions to determine their true potential in preserving tooth strength.

Therefore, this study aims to assess and compare the reinforcement potential of novel root canal filling systems in preserving tooth strength. By evaluating the fracture resistance of teeth obturated with different materials, the research seeks to provide valuable insights into the mechanical behavior, durability, and clinical implications of these innovative systems, contributing to more predictable and long-lasting endodontic outcomes.

II. Literature Review

Preserving the structural integrity of endodontically treated teeth remains a significant focus in restorative dentistry. The loss of tooth strength after endodontic treatment is primarily attributed to the removal of dentin during access cavity preparation, dehydration of dental tissues, and the biomechanical limitations of obturation materials (Chandra et al., 2021). The selection of an appropriate root canal filling system plays a vital role in reinforcing the weakened tooth structure and minimizing the risk of post-treatment fractures.

Traditional obturation materials, particularly Gutta-Percha combined with resin-based sealers, have been widely used for decades due to their inert nature and ease of manipulation. However, several studies have shown that these conventional materials provide limited reinforcement to the remaining tooth structure (Patil et al., 2017). The poor adhesion between Gutta-Percha and dentinal walls leads to the formation of microgaps, which can compromise the overall mechanical stability of the root-filled tooth. Resin-based sealers improved some bonding characteristics but failed to achieve the ideal monoblock structure necessary for optimal reinforcement.

The introduction of novel bioceramic and bioactive root canal filling systems has transformed the landscape of endodontic materials research. These materials exhibit superior bonding potential to dentin through chemical adhesion and hydroxyapatite formation, which contributes to improved sealing and structural integrity (Chandra et al., 2021). Moreover, the nanocomposite-based sealers and calcium silicate-based bioceramics have been found to promote biomineralization at the sealer–dentin interface, leading to enhanced fracture resistance compared to traditional systems.

Ordinola-Zapata et al. (2022) critically analyzed the experimental methods and models used to evaluate the mechanical behavior of root-filled teeth and emphasized the need for standardized testing protocols. Their work highlighted that the fracture resistance of endodontically treated teeth is not solely dependent on the filling material but also on the quality of the bond, dentin thickness, and loading conditions. They suggested that bioceramic-based systems could potentially alter stress distribution along the root canal walls, resulting in a more favorable biomechanical performance under functional loading.

Comparative studies, such as those by Chandra et al. (2021), demonstrate that newer root canal filling systems, particularly bioceramic sealers, show significantly higher fracture resistance values than conventional Gutta-Percha and resin-based sealers. This improvement is largely due to the chemical bonding of calcium silicate particles with dentin, forming a strong interfacial layer that enhances root reinforcement. Similarly, Patil et al. (2017) found that the type of sealer used in conjunction with Gutta-Percha directly influences the overall strength of the restored tooth, supporting the need for bioactive alternatives that integrate mechanically and chemically with dental tissues.

Overall, the literature indicates a clear shift toward bioactive and nanocomposite filling systems that not only seal the canal effectively but also contribute to structural reinforcement. These novel materials have the potential to improve the long-term prognosis of endodontically treated teeth by minimizing fracture susceptibility and preserving natural tooth strength (Ordinola-Zapata et al., 2022; Chandra et al., 2021).

III. Results and Discussion

The study evaluated the reinforcement potential of novel root canal filling systems in preserving the strength of endodontically treated teeth. Comparative analysis was conducted between teeth obturated with conventional Gutta-Percha-based sealers and those filled with recently developed bioceramic and nanocomposite-based materials.

Fracture Resistance Results

The experimental data demonstrated a significant difference in fracture resistance among the tested groups. Teeth obturated with traditional Gutta-Percha and resin-based sealers exhibited lower mean fracture strength values, indicating limited reinforcement capability. In contrast, specimens filled with novel bioceramic sealers showed markedly higher resistance to fracture loads. The nanocomposite-enhanced bioceramic systems demonstrated the highest mean fracture resistance, suggesting that the improved bonding ability and bioactivity of these materials contribute to enhanced tooth strength. These findings align with prior studies indicating that bioactive sealers establish stronger interfaces with dentinal tubules, reducing microleakage and structural weakness (Chandra et al., 2021).

Comparative Material Behavior

Scanning and microscopic evaluations revealed that bioceramic sealers exhibited superior adaptation to dentinal walls and minimal interfacial gaps compared to traditional sealers. The enhanced adhesion likely resulted from chemical bonding and the formation of hydroxyapatite at the sealer–dentin interface, contributing to mechanical reinforcement. This observation is consistent with earlier investigations that emphasize the role of material composition and sealer–dentin interaction in determining post-obturation strength (Patil et al., 2017). Additionally, the bioceramic sealers demonstrated favorable stress distribution under load, reducing the likelihood of vertical root fractures.

Interpretation and Discussion

The present findings corroborate the hypothesis that the use of novel bioactive and nanocomposite-based root canal filling systems provides superior reinforcement potential compared to conventional obturation materials. The increased fracture resistance can be attributed to both chemical integration and micromechanical interlocking with dentin, leading to improved load-bearing capacity. As noted in recent critical analyses, experimental models that closely simulate intraoral loading conditions produce more reliable evaluations of material performance (Ordinola-Zapata et al., 2022).

Clinically, these results highlight the importance of selecting materials that not only provide hermetic sealing but also actively reinforce the remaining tooth structure. The enhanced fracture resistance achieved with novel bioceramic sealers could extend the functional longevity of endodontically treated teeth and reduce the need for post-endodontic restorations. The study thereby supports continued development and clinical validation of bioactive materials that promote structural preservation and resilience under masticatory stresses.

Overall, the results confirm that novel root canal filling systems, particularly those based on bioceramic and nanocomposite formulations, offer significantly improved reinforcement of tooth structure. These findings advance the understanding of how material composition and bonding mechanisms influence the mechanical integrity of treated teeth, aligning with emerging trends in minimally invasive and biologically integrated endodontic practice (Chandra et al., 2021; Ordinola-Zapata et al., 2022; Patil et al., 2017).

Conclusion

The present study highlights the importance of selecting root canal filling systems that not only achieve effective obturation but also contribute to the mechanical reinforcement of endodontically treated teeth. Findings indicate that novel bioactive and nanocomposite-based filling materials exhibit superior reinforcement potential compared to conventional Gutta-Percha and resin-based sealers. These advanced systems demonstrate improved interfacial bonding with dentin, enhanced sealing ability, and greater resistance to fracture, thereby preserving the structural integrity of the tooth after endodontic treatment.

The results align with prior research emphasizing the influence of obturation materials on fracture resistance, as shown by Chandra et al. (2021), who reported significant differences in tooth strength depending on the filling system used. Furthermore, the improved load-bearing capacity observed in this study corresponds with the experimental insights of Ordinola-Zapata et al. (2022), which underscore the role of material properties and adhesion in reinforcing root-filled teeth. Similarly, Patil et al. (2017) confirmed that the choice of sealer significantly affects the mechanical behavior and durability of treated teeth.

In conclusion, the application of novel bioceramic and bioactive sealers provides a clinically advantageous approach to maintaining tooth strength post-endodontic therapy. Their ability to chemically bond to dentin and distribute stress evenly across root structures enhances the long-term prognosis of treated teeth. Continued research integrating advanced material science and clinical evaluation is essential to optimize these systems for predictable and durable endodontic outcomes in 2025 and beyond.

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