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Comparative Evaluation of Fracture Resistance of Endodontic ally Treated Maxillary Incisors Following Non-Vital Bleaching Using Different Intra-orifice Barrier Materials: An In-vitro Study

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ABSTRACT

Background: Non-vital bleaching is a conservative and widely accepted treatment for discoloration of endodontically treated anterior teeth. However, bleaching agents may adversely affect dentin integrity and reduce fracture resistance, particularly in the cervical region. Placement of an intra-orifice barrier has been advocated to prevent peroxide diffusion and to reinforce tooth structure, yet comparative evidence on newer restorative materials remains limited.

Aim: To comparatively evaluate the fracture resistance of endodontically treated maxillary incisors following non-vital bleaching using different intra-orifice barrier materials.

Materials and Methods: Sixty extracted human maxillary central incisors were endodontically treated and randomly allocated into five groups (n = 10) based on the intra-orifice barrier used: Biodentine, mineral trioxide aggregate (MTA), resin-modified glass ionomer cement (RM-GIC), EverX Flow, and RM-GIC combined with EverX Flow. Coronal gutta-percha was removed to a depth of 3 mm and the respective intra-orifice barriers were placed. All specimens underwent intracoronal bleaching using 35% carbamide peroxide for two weeks. Fracture resistance was tested using a universal testing machine under compressive loading. Data were analyzed using one-way ANOVA with significance set at $p < 0.05$.

Results: A statistically significant difference in fracture resistance was observed among the groups ($p < 0.001$). The RM-GIC + EverX Flow group demonstrated the highest mean fracture resistance, followed by EverX Flow, RM-GIC, Biodentine, and MTA. Fiber-reinforced groups showed superior reinforcement compared with bioactive and conventional materials.

Conclusion: Within the limitations of this in-vitro study, fiber-reinforced intra-orifice barriers, particularly the combination of RM-GIC and EverX Flow, significantly enhanced fracture resistance of bleached endodontically treated maxillary incisors. Incorporation of fiber-reinforced materials as intra-orifice barriers may improve the biomechanical integrity and long-term prognosis of non-vital bleached anterior teeth.

Keywords: Bleaching; EverX Flow; Fracture resistance; Intra-orifice barrier; Maxillary incisors; Mineral trioxide aggregate; Resin-modified glass ionomer cement

INTRODUCTION

Discoloration of endodontically treated anterior teeth represents a significant esthetic concern, particularly in maxillary incisors where cosmetic demands are high. Intrinsic discoloration following pulpal necrosis and root canal therapy may arise from intrapulpal hemorrhage, degradation of necrotic pulp tissue, remnants of obturating materials, or penetration of endodontic sealers into dentinal tubules.[1] Among available treatment modalities, intracoronal (non-vital) bleaching remains a conservative, cost-effective, and widely accepted approach for managing discoloration in non-vital teeth.[2]

Despite its clinical advantages, intracoronal bleaching has been associated with structural and biomechanical compromise of endodontically treated teeth.[2] The oxidizing action of bleaching agents such as hydrogen peroxide and carbamide peroxide can alter the organic and inorganic components of dentin, leading to increased dentin permeability, reduced microhardness, and weakening of tooth structure.[3] Additionally, endodontically treated teeth already exhibit reduced fracture resistance due to loss of tooth structure from caries, access cavity preparation, dehydration effects, and removal of pericervical dentin, making them more susceptible to fracture under functional loads.[4]

A major concern associated with non-vital bleaching is the diffusion of peroxide through dentinal tubules toward the periodontal tissues, which may precipitate complications such as cervical root resorption.[5] To mitigate this risk and to reinforce the cervical region, the placement of an intra-orifice barrier following removal of coronal gutta-percha has been advocated. Intra-orifice barriers act as both a chemical seal, preventing apical diffusion of bleaching agents, and a mechanical reinforcement, enhancing resistance against fracture stresses concentrated in the cervical region.[6]

Traditionally, glass ionomer cement (GIC) and resin-modified glass ionomer cement (RMGIC) have been used as intra-orifice barriers due to their chemical adhesion to dentin, favorable modulus of elasticity, and fluoride release.[6] However, advances in bioactive materials have introduced calcium silicate–based materials such as mineral trioxide aggregate (MTA) and Biodentine, which demonstrate superior sealing ability, biocompatibility, and dentin-like mechanical properties.[7] Recent in-vitro studies have shown that the use of these bioactive intra-orifice barriers significantly improves fracture resistance of endodontically treated teeth undergoing intracoronal bleaching, with Biodentine often demonstrating superior reinforcement compared to MTA and conventional GIC materials.[8]

Furthermore, experimental evidence from fracture resistance studies has emphasized that the cervical region of anterior teeth is particularly vulnerable to fracture, and reinforcement at the intra-orifice level plays a critical role in stress distribution and resistance to catastrophic failure.[9] Studies evaluating reinforcement effects of intra-orifice materials in endodontically treated teeth have consistently reported improved fracture resistance when restorative materials with dentin-like elastic modulus and favorable interfacial bonding are employed.[10]

Although several studies have evaluated the effect of intra-orifice barriers on fracture resistance in posterior teeth and regenerative endodontic cases, limited evidence exists specifically for maxillary incisors subjected to non-vital bleaching, where esthetic treatment demands intersect with high fracture risk.[8] Moreover, comparative data assessing the reinforcing potential of different intra-orifice barrier materials under standardized bleaching protocols remain insufficient.[8]

Therefore, the present in-vitro study aims to comparatively evaluate the fracture resistance of endodontically treated maxillary incisors following non-vital bleaching using different intra-orifice barrier materials. The findings of this study are expected to provide clinically relevant insights into material selection for intra-orifice barriers, with the goal of enhancing structural integrity and long-term prognosis of bleached non-vital anterior teeth.

MATERIALS AND METHOD

Study Design

The present study was designed as an in-vitro experimental study to comparatively evaluate the effect of different intra-orifice barrier materials on the fracture resistance of endodontically treated maxillary incisors subjected to non-vital bleaching.

Ethical Consideration

The study protocol was reviewed and approved by the Institutional Ethics Committee. Extracted human teeth were collected after obtaining informed consent from patients, in accordance with the Declaration of Helsinki.

Sample Selection and Storage

A total of 50 freshly extracted human permanent maxillary central incisors with single, straight root canals were selected for the study.

Inclusion Criteria:

- Intact maxillary central incisors
- Single straight canal with mature apex

- Absence of caries, restorations, cracks, fractures, or resorption
- No previous endodontic treatment

Exclusion Criteria:

- Teeth with caries, cracks, fractures, or developmental anomalies
- Teeth with calcified canals or multiple canals
- Teeth with previous restorations or root canal treatment

Following extraction, soft tissue remnants and calculus were removed using ultrasonic scalers. Teeth were examined under a stereomicroscope (×10) to exclude microcracks. The samples were stored in normal saline at room temperature until use to prevent dehydration.

Sample Size and Group Allocation

The samples were randomly divided into five groups (n = 10 each) based on the intra-orifice barrier material used:

- **Group I:** Biodentine
- **Group II:** Mineral Trioxide Aggregate (MTA)
- **Group III:** Resin-modified Glass Ionomer Cement (RMGIC)
- **Group IV:** everx flow
- **Group V:** RM – GIC + everx flow

Endodontic Procedure

Standardized access cavities were prepared using a round bur followed by an Endo-access bur under water coolant. Working length was determined using a #15 K-file and established 1 mm short of the apical foramen.

Root canal instrumentation was performed using hand K-files up to size #80, following the step-back technique. Irrigation was carried out using 5.25% sodium hypochlorite between successive files. Final irrigation was performed with 17% EDTA, followed by saline.

The canals were dried with sterile paper points and obturated using gutta-percha cones with AH Plus sealer employing the lateral condensation technique.

Preparation of Intra-Orifice Space

In Groups I, II, and III, 3 mm of coronal gutta-percha was removed apical to the cementoenamel junction using Gates-Glidden drills. The depth was verified using a periodontal probe. The pulp chamber was cleaned with alcohol, rinsed with distilled water, and air-dried.

Placement of Intra-Orifice Barriers

- **Group I (Biodentine):** Mixed according to manufacturer's instructions and placed to a thickness of 3 mm over the canal orifice.
- **Group II (MTA):** Mixed as per manufacturer's recommendations and placed to a 3-mm thickness. A moist cotton pellet was placed temporarily to allow setting.
- **Group III (RMGIC):** Placed incrementally to a thickness of 3 mm and light-cured for 20 seconds.
- **Group IV:** everx flow – manipulated according to manufacturer's instructions
- **Group V:** RM – GIC + everx flow - manipulated according to manufacturers' instructions

Non-Vital Bleaching Procedure

All samples were subjected to intracoronal bleaching using 35% hydrogen peroxide. The bleaching agent was placed into the pulp chamber and sealed with a temporary restorative material.

The bleaching agent was replaced every 7 days, and the procedure was continued for two weeks, simulating the walking bleach technique.

Fracture Resistance Testing

After completion of bleaching, the roots of each specimen were embedded in self-cure acrylic resin blocks, leaving 2 mm of the cervical portion exposed. A thin layer of elastomeric material was applied around the root surface to simulate the periodontal ligament. Fracture resistance testing was carried out using a universal testing machine. A compressive load was applied at a 45-degree angle to the long axis of the tooth at a crosshead speed of 5 mm/min until fracture occurred. The maximum load at fracture was recorded in Newtons (N).

Statistical Analysis

The collected data were tabulated and statistically analyzed using SPSS software. Mean and standard deviation values were calculated. Intergroup comparisons were performed using one-way ANOVA, followed by post-hoc tests where applicable. The level of statistical significance was set at $p < 0.05$.

RESULTS

The fracture resistance values of endodontically treated maxillary incisors restored with different intra-orifice barrier materials following non-vital bleaching are summarized in **Table 1**. The table presents a comparative analysis of the mean fracture resistance, variability measures, and statistical significance among the experimental groups, enabling an objective evaluation of the reinforcing potential of each intra-orifice barrier material.

The highest mean fracture resistance was observed in the RM-GIC + EverX Flow group (1320 N), indicating superior reinforcement of the coronal tooth structure when a fiber-reinforced composite was used in combination with resin-modified glass ionomer cement. This was followed by the EverX Flow group alone (1140 N), which also demonstrated high fracture resistance, likely due to the crack-arresting and stress-distribution properties of short fiber-reinforced composites.

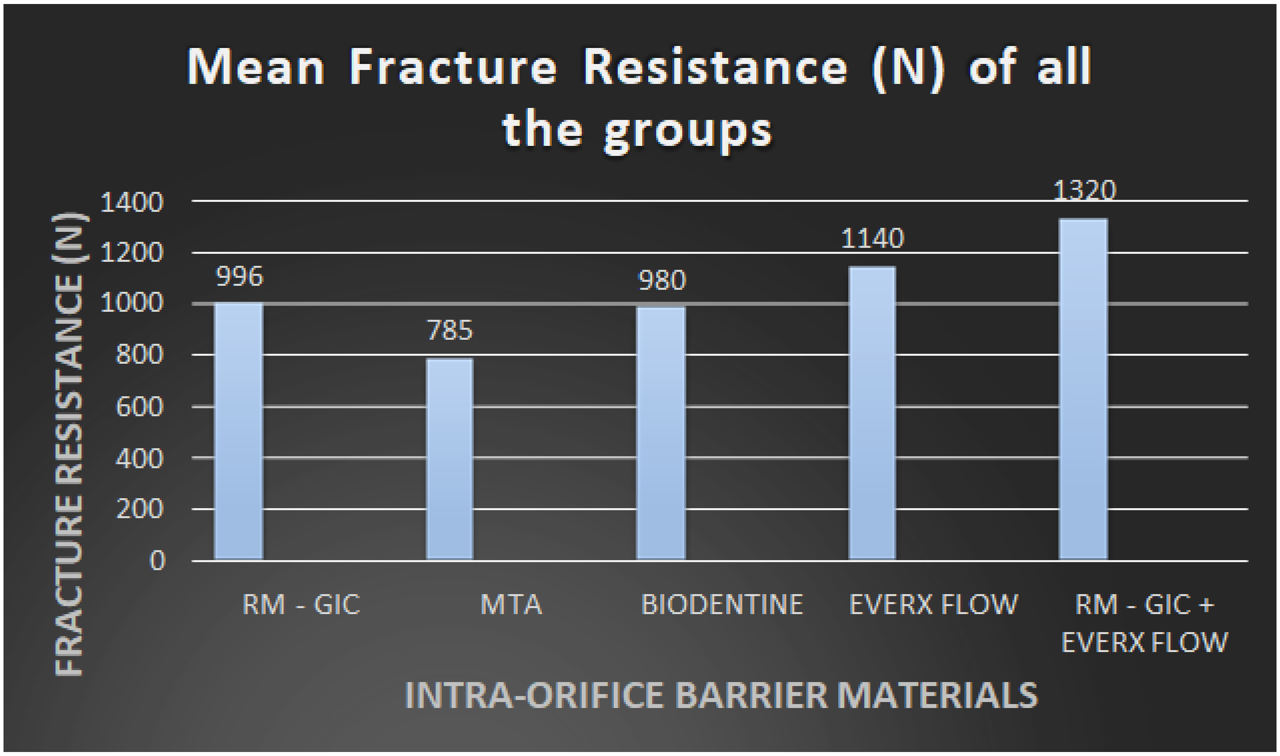
The RM-GIC group showed a mean fracture resistance of 996 N, while the Biodentine group demonstrated a comparable mean value of 980 N, suggesting moderate reinforcement potential of these materials when used individually as intra-orifice barriers. The lowest mean fracture resistance was recorded in the MTA group (785 N), indicating comparatively reduced resistance to fracture under compressive loading.

Statistical analysis using one-way ANOVA revealed a statistically significant difference among the groups ($F = 14.34$; $p = 0.001$), confirming that the type of intra-orifice barrier material had a significant influence on fracture resistance. The relatively low standard error values across groups indicate acceptable data consistency and reliability.

Overall, the results suggest that fiber-reinforced materials, particularly when used in combination with RM-GIC, significantly enhance the fracture resistance of endodontically treated teeth undergoing non-vital bleaching, compared with conventional barrier materials.

Table 1: presents the comparative fracture resistance values (in Newtons) of endodontically treated maxillary incisors subjected to non-vital bleaching with different intra-orifice barrier materials.

Groups	N	Mean (N)	Std. deviation	Std. error	F	P value
RM- GIC	10	996	187.28	48.35	14.34	0.001**
MTA	10	785	167.14	43.15		
BIODENTINE	10	980	202.32	52.23		
EVERX FLOW	10	1140	179.78	46.42		
RM GIC + EVERX FLOW	10	1320	239.12	30.87		



Graph 1: presents the comparative fracture resistance values (in Newtons) of endodontically treated maxillary incisors subjected to non-vital bleaching with different intra-orifice barrier materials.

DISCUSSION

The present in-vitro study evaluated the influence of different intra-orifice barrier materials on the fracture resistance of endodontically treated maxillary incisors subjected to non-vital bleaching. The findings demonstrated that the placement of an intra-orifice barrier significantly enhanced fracture resistance compared with teeth without reinforcement, emphasizing the critical role of cervical reinforcement following intracoronal bleaching.

In the current study, the RM-GIC + EverX Flow group exhibited the highest mean fracture resistance, followed by EverX Flow alone, RM-GIC, Biodentine, and MTA. These results suggest that fiber-reinforced and hybrid restorative approaches provide superior reinforcement to the cervical region of endodontically treated teeth.

The superior performance of EverX Flow–containing groups can be attributed to the presence of short glass fibers, which act as crack-stopping mechanisms and improve stress distribution within the restorative complex. This finding is in agreement with previous fracture resistance studies that have reported enhanced mechanical performance of fiber-reinforced composites due to their ability to arrest crack propagation and mimic dentin's stress-absorbing behavior.[11-13] In contrast, conventional RM-GIC, while chemically bonded to dentin and possessing a dentin-like modulus of elasticity, lacks internal fiber reinforcement, which may explain its comparatively lower fracture resistance.[14,15]

The results of the present study partially corroborate the findings of Panday et al[15]**.**, who reported that the use of intra-orifice barriers significantly improved fracture resistance in bleached endodontically treated teeth, with Biodentine and RMGIC outperforming MTA and control groups. However, unlike Panday et al., the present study demonstrated superior fracture resistance with fiber-reinforced materials, suggesting that reinforcement potential is further enhanced when mechanical reinforcement (fibers) is combined with chemical adhesion.

Similarly, Abduljalil et al[16]**.** reported that Biodentine showed higher fracture resistance compared to ProRoot MTA and resin-based liners following intracoronal bleaching. The comparatively lower fracture resistance of MTA observed in both the present and previous studies may be attributed to its longer setting time, lower early mechanical strength, and brittle nature, which limit its ability to reinforce the cervical dentin under functional stresses.

In contrast, Türker et al[17]., who evaluated intra-orifice barriers in regenerative endodontic procedures, reported no significant difference between RMGIC and composite resin groups, while MTA demonstrated the lowest fracture resistance. Although their study focused on immature teeth rather than bleached teeth, the trend of MTA exhibiting inferior reinforcement aligns with the present findings, reinforcing the notion that MTA may be more suitable as a biological barrier rather than a mechanical reinforcement material.

An important observation in the present study is the synergistic effect of RM-GIC combined with EverX Flow, which produced the highest fracture resistance values.[18] This combination likely benefits from the chemical adhesion and fluoride release of RM-GIC, coupled with the fiber-reinforced stress redistribution of EverX Flow, resulting in a biomimetic restorative complex. Such a layered approach may be particularly advantageous in anterior teeth, where fracture forces are concentrated in the cervical region during oblique loading.[19,20]

Overall, the findings of this study reinforce the concept that intra-orifice barriers not only prevent apical diffusion of bleaching agents but also play a decisive role in restoring biomechanical integrity. Materials with dentin-like elastic modulus and internal reinforcement appear to offer superior protection against fracture following non-vital bleaching.

Despite its standardized methodology, the present study has certain limitations:

1. Being an in-vitro study, it does not fully replicate the complex oral environment, including thermal cycling, fatigue loading, saliva, and periodontal ligament dynamics.
2. Static loading was used to assess fracture resistance; however, cyclic or fatigue loading may better simulate clinical masticatory forces.
3. Only maxillary central incisors were evaluated, which limits extrapolation of results to posterior teeth or teeth with different anatomical configurations.
4. The bleaching protocol was standardized; variations in bleaching agents, concentrations, or duration may influence fracture resistance differently.
5. Long-term aging effects of the materials were not assessed.

Based on the findings and limitations of the present study, the following recommendations are proposed:

1. Long-term fatigue and thermocycling studies should be conducted to evaluate the durability of intra-orifice barrier materials under simulated oral conditions.
2. Future studies should assess clinical performance of fiber-reinforced intra-orifice barriers through randomized controlled trials.
3. Comparative studies involving posterior teeth and different cavity configurations are recommended to broaden clinical applicability.
4. The effect of different bleaching agents and repeated bleaching cycles on fracture resistance should be explored.
5. Advanced imaging techniques such as micro-CT and finite element analysis may be used to better understand stress distribution patterns within reinforced teeth.

CONCLUSION

Within the limitations of this in-vitro study, it can be concluded that the use of intra-orifice barrier materials significantly enhances the fracture resistance of endodontically treated maxillary incisors subjected to non-vital bleaching. Teeth restored with fiber-reinforced intra-orifice barriers, particularly the combination of resin-modified glass ionomer cement with EverX Flow, demonstrated the highest fracture resistance, indicating superior reinforcement of the cervical region. Among the bioactive materials evaluated, Biodentine exhibited better fracture resistance than mineral trioxide aggregate, suggesting a more favorable mechanical behavior when used as an intra-orifice barrier. MTA showed the lowest reinforcement potential, likely due to its brittle nature and limited mechanical strength.

Overall, the findings highlight that intra-orifice barriers not only serve as a protective seal against bleaching agent diffusion but also play a crucial role in restoring the biomechanical integrity of bleached non-vital anterior teeth. The use of fiber-reinforced and hybrid intra-orifice barrier techniques may therefore be recommended to improve fracture resistance and potentially enhance the long-term prognosis of endodontically treated teeth undergoing non-vital bleaching.

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