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ORIGINAL RESEARCH

Evaluation of the Fracture Resistance of Endodontically Treated Teeth Restored with Bioceramic-Based Materials

Dr. Atul Ashok Jadhav

Assistant Professor, Department of Dentistry, Rajiv Gandhi Medical College and Chatrapati Shivaji Maharaj Hospital, Kalwa Thane, India

Corresponding Author
Dr. Atul Ashok Jadhav
Assistant Professor, Department of Dentistry, Rajiv Gandhi Medical College and Chatrapati Shivaji Maharaj Hospital, Kalwa Thane, India
Email: jsmatuljadhav@gmail.com

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ABSTRACT
Background: The long-term success of endodontically treated teeth depends on the ability of restorative materials to withstand functional forces and prevent fracture. Bioceramic-based materials have emerged as potential alternatives for restoring teeth due to their biocompatibility, sealing ability, and mechanical properties. This study evaluates the fracture resistance of endodontically treated teeth restored using bioceramic-based materials compared to conventional restorative materials. **Materials and Methods**: This in vitro study involved 60 extracted human premolars randomly divided into three groups (n=20 each): Group A (restored with a bioceramic sealer and core material), Group B (restored with composite resin), and Group C (control, no restoration). Standardized endodontic treatment was performed on all samples. Each tooth underwent thermocycling for aging simulation, followed by load application at a 45° angle in a universal testing machine until fracture. The maximum load at fracture (in Newtons) was recorded and analyzed using ANOVA and post hoc tests ($p<0.05$). **Results**: The fracture resistance values were significantly higher in Group A (1200 ± 150 N) compared to Group B (950 ± 100 N) and Group C (700 ± 80 N). Post hoc analysis revealed that bioceramic-based materials provided superior reinforcement to endodontically treated teeth. Failure modes predominantly involved favorable fractures in Group A, while Groups B and C exhibited higher rates of catastrophic fractures. **Conclusion**: Bioceramic-based restorative materials significantly enhance the fracture resistance of endodontically treated teeth compared to composite resin and untreated teeth. These materials could be considered a promising choice for the reinforcement of weakened dental structures. Further clinical studies are recommended to validate these findings.
Keywords: Fracture resistance, endodontically treated teeth, bioceramic materials, composite resin, dental restoration.

INTRODUCTION
Endodontically treated teeth are inherently weaker than vital teeth due to the removal of tooth structure during access cavity preparation, the loss of dentinal elasticity, and changes in collagen cross-linking, which collectively increase their susceptibility to fracture (1,2). This structural compromise necessitates the use of restorative materials and techniques that not only seal the root canal system effectively but also reinforce the remaining tooth structure to withstand functional forces.
Bioceramic-based materials have gained significant attention in endodontics and restorative dentistry due to their superior biocompatibility, bioactivity, and excellent sealing properties. These materials are calcium silicate-based, hydrophilic, and capable of forming hydroxyapatite upon contact with tissue fluids, promoting a superior bond with dentinal walls (3,4). In addition to their endodontic applications, bioceramic-based materials are now being explored as potential restorative options to improve the fracture resistance of weakened teeth (5).
Conventional restorative materials, such as composite resins, have long been utilized for restoring endodontically treated teeth. While these materials offer adequate esthetics and mechanical properties, their ability to reinforce the tooth structure under high masticatory loads remains limited (6,7). Recent studies have shown that bioceramic materials not only provide better sealing of the root canal system but also improve the fracture resistance of the restored teeth,

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owing to their excellent adhesion and mechanical properties (8).
This study aims to evaluate and compare the fracture resistance of endodontically treated teeth restored with bioceramic-based materials and conventional composite resin. Understanding the role of bioceramic materials in reinforcing tooth structure could provide valuable insights for clinical decision-making and improve the longevity of endodontically treated teeth.

MATERIALS AND METHODS

Study Design and Sample Selection

This in vitro experimental study was conducted in lokmanya tilak nursing home kores hospital (Thane Municipal Corporation) Vartak nagar Thane on 60 extracted human maxillary premolars with similar dimensions and no visible caries, cracks, or restorations. Teeth with external defects or root fractures were excluded. The samples were randomly divided into three groups (n=20 each):

- **Group A:** Restored with bioceramic-based material (sealer and core).
- **Group B:** Restored with composite resin.
- **Group C:** Control group (endodontically treated, no restoration).

Endodontic Procedure

All teeth underwent standardized root canal treatment. Access cavities were prepared using a high-speed handpiece with diamond burs under copious water cooling. Cleaning and shaping of the root canals were performed using rotary nickel-titanium files (Protaper Universal, Dentsply) up to size F3. Irrigation was carried out using 2.5% sodium hypochlorite followed by 17% EDTA for smear layer removal. The canals were dried with paper points and obturated with gutta-percha and a bioceramic sealer (EndoSequence BC Sealer, Brasseler).

Restorative Procedures

- **Group A:** The access cavity was restored with bioceramic-based material (EndoSequence BC RRM, Brasseler) as the core material, following the manufacturer's instructions.
- **Group B:** Composite resin (Filtek Z350, 3M ESPE) was used to restore the access cavity. A self-etch adhesive system (Scotchbond Universal, 3M ESPE) was applied, and incremental composite placement was performed.
- **Group C:** Teeth received no coronal restoration after obturation.

Aging Simulation

All specimens were subjected to thermocycling (10,000 cycles) between 5°C and 55°C with a dwell time of 30 seconds to simulate oral conditions.

Fracture Resistance Testing

The specimens were embedded in acrylic blocks, leaving 2 mm of the cervical area exposed to mimic the periodontal ligament. Each tooth was mounted in a universal testing machine (Instron, USA). A compressive load was applied at a 45° angle to the palatal cusp using a stainless steel cylindrical rod with a crosshead speed of 1 mm/min until fracture.

Outcome Measurement

The maximum load at fracture (in Newtons) was recorded. Failure modes were categorized as either favorable (restorable) or catastrophic (non-restorable).

Statistical Analysis

The data were analyzed using one-way ANOVA to compare the fracture resistance among the three groups, followed by post hoc Tukey tests for pairwise comparisons. Statistical significance was set at $p<0.05$. All analyses were performed using SPSS software (version 25.0).

RESULTS

The fracture resistance of the three groups was recorded and analyzed. Group A (bioceramic-based materials) demonstrated the highest mean fracture resistance, followed by Group B (composite resin), with Group C (control) showing the lowest values. The results are presented in Table 1.

Fracture Resistance Values

Group	n	Mean Fracture Resistance (N)	Standard Deviation (SD)	Range (N)
Group A	20	1200	150	950–1400
Group B	20	950	100	800–1150
Group C	20	700	80	600–850

Statistical Analysis

The one-way ANOVA revealed a significant difference in fracture resistance among the three groups (**$p < 0.001$**). Post hoc Tukey's tests indicated that:

- Group A had significantly higher fracture resistance than Group B (**$p < 0.01$**) and Group C (**$p < 0.001$**).
- Group B had significantly higher fracture resistance than Group C (**$p < 0.05$**).

Failure Modes

The failure modes are detailed in Table 2. Group A exhibited predominantly favorable fractures (70%), while Groups B and C showed higher rates of catastrophic fractures.

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Group	Failure Mode	Frequency (%)
Group A	Favorable (Restorable)	14 (70%)
	Catastrophic	6 (30%)
Group B	Favorable (Restorable)	10 (50%)
	Catastrophic	10 (50%)
Group C	Favorable (Restorable)	4 (20%)
	Catastrophic	16 (80%)

Bioceramic-based materials significantly enhanced the fracture resistance of endodontically treated teeth and showed more favorable failure modes compared to composite resin and untreated controls.

DISCUSSION

The present study evaluated the fracture resistance of endodontically treated teeth restored with bioceramic-based materials, composite resin, and untreated control teeth. The results demonstrated that teeth restored with bioceramic-based materials exhibited significantly higher fracture resistance compared to composite resin and untreated teeth. These findings align with previous research suggesting that bioceramic materials provide superior mechanical reinforcement due to their chemical adhesion to dentinal walls and favorable physical properties (1,2).

Bioceramic materials, such as EndoSequence BC Sealer and BC RRM, form a strong bond with dentin through the formation of hydroxyapatite, which enhances the mechanical integration and distributes stress more effectively (3). This property likely contributed to the higher fracture resistance observed in Group A, supporting earlier studies that reported similar results in weakened tooth structures (4). Additionally, the favorable failure modes (restorable fractures) observed in Group A suggest that bioceramic materials may offer clinical advantages by preserving tooth integrity under load (5).

Composite resin, although widely used for the restoration of endodontically treated teeth, exhibited lower fracture resistance compared to bioceramic materials. Composite resins rely on micromechanical retention and adhesive bonding, which may not provide the same level of structural reinforcement as bioceramic materials (6). This limitation has been reported in earlier studies, emphasizing the need for alternative materials that can improve the longevity of restorations (7).

The untreated control group (Group C) showed the lowest fracture resistance, highlighting the inherent structural vulnerability of endodontically treated teeth. This finding underscores the necessity of restoring such teeth with materials capable of reinforcing the residual structure to prevent catastrophic fractures (8).

Thermocycling was incorporated in this study to simulate the thermal stresses experienced in the oral environment, which can influence the mechanical behavior of restorative materials (9). The significant differences observed among the groups after thermocycling further validate the durability of bioceramic materials under clinically relevant conditions.

The failure modes in this study provide additional insights into the performance of the tested materials. The predominance of catastrophic fractures in Groups B and C indicates the limited ability of composite resin and untreated teeth to distribute stress effectively. Conversely, the favorable fractures in Group A suggest that bioceramic materials may mitigate stress concentrations, reducing the likelihood of irreparable damage (10).

Limitations and Future Directions

This study was conducted in vitro, which may not fully replicate the complex conditions of the oral environment, such as occlusal loading and dynamic forces. Future studies should include clinical trials to evaluate the long-term performance of bioceramic materials in vivo. Additionally, the interaction of bioceramic materials with different types of adhesive systems warrants further exploration to optimize their application in restorative dentistry.

CONCLUSION

The findings of this study highlight the potential of bioceramic-based materials in enhancing the fracture resistance of endodontically treated teeth while promoting favorable failure patterns. These materials represent a promising alternative for reinforcing weakened dental structures, with potential implications for improving the clinical outcomes of endodontic therapy.

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