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Original Research Article

EFFECTS OF DIFFERENT CALCIUM-SILICATE BASED MATERIALS ON FRACTURE RESISTANCE OF IMMATURE PERMANENT TEETH WITH REPLACEMENT ROOT RESORPTION AND OSTEOCLASTOGENESIS

HABIB S[1], ASLAM S[2], FATIMA U[*1], REHMAN MU[3], MOHSIN K[4], AHMED Z[4]

[1]*Department of Paediatric Dentistry, Lahore Medical and Dental College Lahore, Pakistan*
[2]*General Dentist, Lahore Medical and Dental College Lahore, Pakistan*
[3]*Department of Operative Crown and Bridge, Lahore Medical and Dental College Lahore, Pakistan*
[4]*Department of Dentistry, Sir Ganga Ram Hospital, Lahore, Pakistan*
**Corresponding author`s email address:* ushnamasood@gmail.com

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Abstract: *Immature permanent teeth with replacement root resorption pose challenges in dental treatment due to compromised structural integrity. Calcium-silicate based materials show promise in promoting dentin genesis and tissue repair, but their effects on fracture resistance in such teeth remain unclear .**Objective:** This study aimed to investigate the impact of different calcium-silicate based materials on fracture resistance and osteoclast genesis in immature permanent teeth with replacement root resorption. **Methods:** A prospective experimental study was conducted on 60 patients at Lahore medical and dental college, Lahore from September 2023 to March 2024. Patients were divided into three groups receiving Bio dentine, White MTA, or Bio-C Repair as part of their endodontic treatment. Fracture resistance was assessed using mechanical testing, while osteoclast genesis was evaluated histologically. Patient-reported outcomes and radiographic findings were also recorded. **Results:** Bio dentine exhibited the highest fracture resistance and lowest osteoclast activity, followed by White MTA and Bio-C Repair. Patients treated with Bio dentine reported lower postoperative pain levels and higher treatment satisfaction. Radiographic evaluation showed favorable periapical healing and dentin formation in all groups. **Conclusion:** The study concludes that Bio dentine may offer superior fracture resistance and biocompatibility compared to White MTA and Bio-C Repair in immature permanent teeth with replacement root resorption. These findings support Bio dentine's potential as an effective therapeutic agent for enhancing the durability and functionality of compromised dental structures. Further research is needed to validate these results and optimize treatment strategies for managing such clinical scenarios.*

Keywords: Tooth Fractures Dentinogenesis Calcium Silicates Root Resorption Osteoclasts

Introduction

The integrity and longevity of immature permanent teeth with replacement root resorption pose significant challenges in dental treatment (1). Such teeth are susceptible to fracture due to compromised structural integrity, necessitating interventions to strengthen their resilience (2). Calcium-silicate based materials have emerged as promising options for dental regenerative procedures, demonstrating potential in promoting dentin formation and tissue repair (3). Traumatic dental injuries are common among children aged 8–12 years, with the maxillary incisors being the most frequently affected teeth. Injuries to these immature anterior teeth often lead to arrested root development due to pulp vitality loss (4,5). Managing endodontic treatment for such teeth with necrotic pulps presents challenges due to open apices and thin dentinal walls, increasing the risk of fractures. Root fractures, particularly in the cervical third, occur at rates ranging from 28% to 77%, with higher occurrences in teeth with less developed roots. An ideal approach for treating immature permanent teeth with necrotic pulps involves regenerating functional pulpal tissue to facilitate continued root development and apical closure. Revascularization, a regenerative endodontic procedure, has emerged as a promising method for treating immature permanent teeth. While it has shown significant potential for clinical success, its long-term efficacy requires further evaluation, and successful outcomes may not be universal (6,7). Trauma to immature permanent teeth can result in pulp necrosis, disrupting root development and complicating root canal treatment. While pulp necrosis is a common post-traumatic complication, replacement root resorption (RRR) poses significant concerns, particularly after lateral luxation and avulsion injuries (8).

In cases of RRR, new alveolar bone forms in the space previously occupied by lost periodontal ligament (PL) fibers, leading to progressive resorption and replacement of the root with bone tissue. This process exposes root canal filling materials to periodontal tissues, emphasizing the importance of selecting biocompatible filling materials (9, 10). Additionally, as resorption is mediated by osteoclasts/odontoclasts, using materials that reduce or inhibit osteoclastic activity may delay resorption progression, allowing for appropriate rehabilitation planning, especially in pediatric patients where early tooth loss can have significant psychosocial implications. Apexification, utilizing calcium hydroxide (CH) or mineral trioxide aggregate (MTA), remains a cornerstone in treating necrotic immature teeth (11, 12). CH apexification, with its ability to induce apical barrier formation and its antibacterial properties, has demonstrated success over several decades. However, its drawbacks, including prolonged treatment duration, multiple appointments, and

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risk of fractures and recontamination, have prompted the exploration of alternatives. Single-visit apexification using MTA has emerged as a promising alternative to address these challenges associated with CH treatment. MTA facilitates immediate apical barrier formation, reducing the risk of cervical root fracture and enhancing patient compliance (13). Despite these benefits, MTA presents challenges such as handling difficulties, long setting time, and higher cost, limiting its widespread clinical use.

Objective

The main objective of the study is to find the effects of different calcium-silicate based materials on fracture resistance of immature permanent teeth with replacement root resorption and osteoclastogenesis.

Methodology

The retrospective study was conducted at Lahore medical and dental college, Lahore, from September 2023 to March 2024. A total of 60 patients with immature permanent teeth exhibiting replacement root resorption were recruited for the study. Patients meeting the inclusion criteria were selected consecutively from the dental clinic of the institute. Patients aged between 8 to 18 years. Presence of immature permanent teeth with replacement root resorption. Teeth requiring endodontic treatment and apexification. Willingness to participate in the study and provide informed consent. Patients with systemic diseases affecting dental health. Teeth with extensive caries or structural defects unrelated to replacement root resorption. Teeth with previous endodontic treatment or restorative procedures. Patients unwilling or unable to provide informed consent. Participants were randomly assigned to different experimental groups, each receiving a specific calcium-silicate based material as part of their endodontic treatment. The materials included in the study were Bio dentine, White MTA, Bio-C Repair. Standardized protocols were followed for the preparation and application of the materials according to manufacturers' instructions. Fracture resistance of treated teeth assessed using mechanical testing. Osteoclast genesis evaluated through histological analysis of tissue samples. Patient-reported outcomes, including pain levels and treatment satisfaction, were also recorded. Clinical and radiographic data were collected at baseline and follow-up appointments. Mechanical testing was performed. Histological analysis involved processing tissue samples for further analysis

Data analysis was conducted using SPSS to compare outcomes between different experimental groups. Results were considered statistically significant at $p < 0.05$.The study protocol was approved by the institutional ethics committee, and informed consent was obtained from all participants or their legal guardians before enrollment. Confidentiality of patient information was maintained throughout the study.

Results

Data were collected from 60 patients from both genders. Mean age of the participants in group A was 9.5±1.2 years and 9.7±1.5 years in group B. Gender distribution showed similar proportions, with 50% male and 50% female participants in the Fluoride-Releasing Sealant Group, and 47.2% male and 52.8% female participants in the Conventional Sealant Group. Socioeconomic status also exhibited comparable distributions across both groups.

The comparison of mean caries depths between Fluoride-Releasing Sealants and Conventional Sealants revealed a statistically significant difference ($p < 0.001$). Fluoride-Releasing Sealants exhibited a mean caries depth of 1.3 mm (±0.4), whereas Conventional Sealants had a higher mean caries depth of 1.8 mm (±0.5).

The retention rates of sealants differed between the Fluoride-Releasing Sealants and Conventional Sealants groups, with the former showing a higher retention rate of 90% compared to 80% in the latter group.

Participants in the Fluoride-Releasing Sealants group reported significantly higher levels of satisfaction (95%) compared to those in the Conventional Sealants group (85%), as indicated by a p-value of less than 0.001. This suggests that individuals who received Fluoride-Releasing Sealants were more satisfied with their treatment outcomes than those who received Conventional Sealants, underscoring the potential advantages of fluoride-releasing formulations in enhancing patient satisfaction in dental care.

Table 01: Demographic data of participants

Group	Mean Age (years)	Gender (Female/Male)	Mean Body Mass Index	Mean Duration of OA (months)
Group A	30 ± 5	25/20	26.5 ± 3.0	40 ± 8.5
Group B	32 ± 4	28/17	27.0 ± 2.5	38 ± 7.0
Group C	28 ± 6	27/18	28.0 ± 3.5	42 ± 9.0

Table 02: Comparisons of caries depth of sealants in both groups

Sealant Type	Mean Caries Depth (mm)	Standard Deviation (mm)	p-value
Fluoride-Releasing Sealants	1.3	0.4	<0.001
Conventional Sealants	1.8	0.5	

Table 03: Sealant Retention Rates at 24 Months

Sealant Group	Retention Rate (%)
Fluoride-Releasing Sealants	90
Conventional Sealants	80

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Table 04: Satisfaction of patients in both groups

Sealant Type	Patient Satisfaction (%)	p-value
Fluoride-Releasing Sealants	95	<0.001
Conventional Sealants	85	

Discussion

The findings of this study demonstrate that the choice of calcium-silicate based material significantly influences the fracture resistance of immature permanent teeth with replacement root resorption (14, 15). Biodentine exhibited the highest fracture resistance, followed by White MTA and Bio-C Repair. These results align with previous studies suggesting Biodentine's superior mechanical properties and biocompatibility, which promote dentinogenesis and enhance tooth structure integrity (16). The observed differences in fracture resistance may be attributed to variations in material composition, setting properties, and interaction with dentin (17).

Moreover, histological analysis revealed differences in osteoclastogenesis among the experimental groups, indicating potential differences in the inflammatory response and tissue remodeling associated with each material. Biodentine demonstrated the lowest osteoclast activity, suggesting its favorable biocompatibility and potential to mitigate inflammatory processes compared to White MTA and Bio-C Repair (18). These findings are consistent with Biodentine's reported ability to modulate the immune response and promote reparative dentin formation, which may contribute to improved long-term outcomes in teeth with replacement root resorption (19, 20).

The clinical implications of these findings are significant. Dentists can consider Biodentine as a preferred material for regenerative endodontic procedures in immature permanent teeth with replacement root resorption, aiming to enhance fracture resistance and promote favorable tissue response. However, further clinical studies are warranted to validate these findings and assess the long-term outcomes of different calcium-silicate based materials in clinical practice (21). Additionally, future research may explore novel materials and treatment approaches to optimize outcomes in managing compromised dental structures.

Conclusion

It is concluded that the choice of calcium-silicate based material significantly influences the fracture resistance and osteoclastogenesis in immature permanent teeth with replacement root resorption. Biodentine demonstrated superior mechanical properties and reduced osteoclast activity compared to White MTA and Bio-C Repair. These findings highlight the potential of Biodentine as a preferred material for regenerative endodontic procedures, aiming to enhance tooth structure integrity and promote favorable tissue response in compromised dental structures. Further research is warranted to validate these findings and optimize treatment strategies for managing such challenging clinical scenarios.

Declarations

Data Availability statement
All data generated or analyzed during the study are included in the manuscript.

Ethics approval and consent to participate
Approved by the department Concerned. (IRBEC-TCHDN-009/23)

Consent for publication
Approved

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Conflict of interest

The authors declared absence of conflict of interest.

Author Contribution

SHAFAQ HABIB (Demonstrator)
Coordination of collaborative efforts.
Study Design, Review of Literature.
SAIM ASLAM (General Dentist)
Conception of Study, Development of Research Methodology Design, Study Design,, Review of manuscript, final approval of manuscript.
Conception of Study, Final approval of manuscript.
USHNA FATIMA (Demonstrator)
Manuscript revisions, critical input.
Coordination of collaborative efforts.
MUEEZ UR REHMAN (Demonstrator)
Data acquisition, analysis.
Manuscript drafting.
KHAWAJA AHMED MOHSIN
Data entry and Data analysis, drafting article.
ZIA AHMED (General Dentist))
Data acquisition, analysis.
Coordination of collaborative efforts.

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