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Fracture Resistance of Molars with Simulated Strip Perforation Repaired with Calcium Silicate Based & Bioceramic Root Repair Materials – An In-Vitro Study.

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KEYWORDS

Biodentine, Bio-C Root Repair, Fracture resistance, MTA, Strip perforation

ABSTRACT:

Aim: This in-vitro study assessed the effect of simulated strip perforations on the fracture resistance of mandibular molars and compared three repair materials: Biodentine, Mineral Trioxide Aggregate (MTA), and Bio-C Root Repair.

Materials and Methods: Fifty extracted mandibular molars were divided into five groups (n=10). Group I: intact teeth (negative control); Group II: untreated strip perforations (positive control); Groups III–V: perforations repaired with Biodentine, MTA, and Bio-C respectively. Standardized perforations were created in the mesial root, repaired using a sandwich technique, and restored with composite. Samples were subjected to compressive loading in a universal testing machine. Data were analyzed using ANOVA and post-hoc tests.

Results: Strip perforation significantly reduced fracture resistance ($p<0.001$). Intact teeth showed the highest mean resistance (694.4 ± 60.49 N), while untreated perforations exhibited the lowest (273.9 ± 96.18 N). Bio-C demonstrated the highest reinforcement (685.2 ± 89.18 N), comparable to intact teeth and significantly superior to Biodentine (450.5 ± 143.15 N) and MTA (452.3 ± 126.62 N), which showed similar outcomes.

Conclusion: Strip perforations greatly compromise tooth strength. Bio-C Root Repair material restored fracture resistance closest to intact teeth, making it a promising option for clinical management. Biodentine and MTA offered moderate but comparable reinforcement.

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Introduction:

Root canal therapy (RCT) is one of the vital procedures in endodontics which aims at preserving natural teeth by removing infected or damaged pulp tissue. (1) Despite the high success rate of root canal therapy, complications can arise at any stage. One such complication is perforation, which may occur during access cavity preparation, root canal instrumentation, post-space preparation, root canal preparation with internal or external resorption, or the removal of a considerable amount of dentin around separated instruments. (2) Perforations lead to the breakdown of the dentine root wall or floor, as well as the surrounding cementum. This communication compromises the health of the periradicular tissues and threatens the viability of the tooth. (3)

Among the various types of perforations, strip perforation (SP) poses unique challenges due to its structural and clinical characteristics. "Stripping" is a type of lateral perforation resulting from over-instrumentation through a thin root wall, typically occurring on the inner wall of a curved canal, such as the distal wall of the mesial roots in mandibular first molars." (2) Strip Perforations (SPs) differ from other perforations in their large, affected area, irregular perforation site edge, and difficulty in perforation sealing. (4)

Failure to promptly diagnose and treat root perforations can result in complications and potential tooth loss. (5) Therefore, early diagnosis of perforation and its appropriate treatment are crucial to the long-term survival of the affected tooth.

For repair of root perforations, mineral trioxide aggregate (MTA) has long been regarded as the best option. Effective sealing, biocompatibility, antimicrobial activity, radiopacity, and the capacity to set even in the presence of blood are only a few of its advantageous qualities. (6) More recent bioceramic materials have been developed to overcome the drawbacks of MTA.

Bio-C Repair (BC) (Angelus, Londrina, Brazil), a newly introduced ready-to use bioceramic material, is now available in a threaded syringe for endodontic use, enhancing handling and insertion while improving efficiency and saving time. This material has similar cytotoxicity, biocompatibility, and biomineralization properties to MTA. (7)

Similarly, Biodentine, a calcium silicate-based bioactive material with a high alkaline pH and excellent biocompatibility, it is a suitable material for perforation repair. (8)

This research addresses the following key questions:

1. Does strip perforation affect the fracture resistance of teeth?

2. Do different root repair materials influence the fracture resistance of teeth with strip perforation?

Through an in-vitro experimental design, this study aims to provide comprehensive insights into the impact of repair materials on tooth integrity, ultimately guiding clinical practice and improving treatment outcomes.

Materials And Methodology:

Sample preparation

Fifty extracted human mandibular molars were collected for study. After cleaning with 3% NaOCl and an ultrasonic scaler, their anatomy and root curvature were examined via radiovisiography. Excluded teeth were whose mesial root diameters were more than 20% of the mean. Selected teeth were stored in distilled water at 4°C until use.

Procedure:

Standardized access cavities were prepared in all molars using diamond and Endo Access burs. Apical patency was confirmed with a #10 K-file, and the working length was set 0.5 mm short of the apex to ensure effective cleaning while avoiding over-instrumentation.

Root canal instrumentation following a sequential technique, starting with #10 and #15 K-Files to prepare the glide path & Hero Gold rotary files (#20 and #25, 0.04 taper) were used for shaping at 300 rpm and 1.5–2 Ncm torque. RC Help lubricant and 3% NaOCl irrigant were used throughout, along with saline to flush debris. A final rinse with 17% EDTA was used to remove the smear layer. Canals were then dried with sterile paper points ensuring a clean and moisture-free environment.

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The molars where then divided into five main groups using simple random sampling by lottery method as follows:

Group I (Negative Control): No strip perforation (SP) was created, and the teeth were left intact. (n=10)

Group II (Positive Control): Strip perforation was created but not repaired; only gutta-percha (Diadent Group International, Korea) was used. (n=10)

Group III (Biodentine Group): Strip Perforation was repaired using Biodentine (Septodont, St. Maur-des-Fossés, France) (n=10) Materials and Methodology

Group IV (MTA Group): Strip Perforation was repaired using Mineral Trioxide Aggregate (Dentsply Tulsa Dental, Tulsa, OK, USA) (n=10)

Group V (BIO-C Root Repair Group): Strip Perforation was repaired using BIO-C Root Repair Material. (Angelus, Londrina, Brazil) (n=10)

Simulated perforations (SPs) were created on the distal surface of the coronal third of the mesial root in Groups II to IV. The site was marked 3 mm below the furcation, and the distance from the perforation to the mesio-buccal cusp tip was measured using a digital caliper. Strip perforations were created sequentially using #1–3 Gates Glidden drills for standardization. Roots were embedded in moist sponge to prevent displacement during condensation.

Fig. 1 Simulation of Strip Perforation Using GG drills

Group I canals were fully obturated with gutta-percha and AH Plus sealer using warm vertical compaction. In Groups II-V, a "sandwich technique" was used: gutta-percha was cut at the perforation level and compacted to fill up to that point. Groups III-V left space above the gutta-percha for root repair materials, sealing the lower canal first to prevent extrusion and ensure a durable perforation seal.

In Group III - Biodentine was mixed per manufacturer instructions to a putty-like consistency. After that, an MTA carrier and hand pluggers were used to load and place it into the perforation location.

In Group IV - Pro-Root MTA was mixed in a 3:1 powder-to-liquid ratio to a putty-like consistency within 30 seconds. After that, an MTA carrier and hand pluggers were used to load and place it into the perforation location.

Group V - BIO-C Root Repair Material Group: BIO-C Root Repair material (Angelus, Londrina, Brazil), a pre-mixed paste was directly packed into SP areas using MTA Carrier (Waldent, India) and hand pluggers (GDC, India).

Fig. 2 Placement of root Repair Material with MTA Carrier

Fig. 3 Root Repair Material filling strip perforation defect.

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After removing the teeth from the sponge, any extra material was removed using a scalpel. All molars were then restored with composite resin (3M ESPE, Seefeld, Germany) restoration with increment layering technique, wrapped in wet gauze, and placed in an incubator (Bio-Technics India), allowing to set for 24 hours at 37°C under 100% humidity before performing fracture resistance tests. Double blinding was done prior to the fracture resistance test.

Fig. 4 Compressive loading on Occlusal Surface of Molars in Universal Testing Machine

Fracture Resistance Tests:

The apical third of all molar roots was carefully covered with a thin layer of polyether impression material (3M ESPE, Seefeld, Germany) to simulate the natural periodontal ligament and provide a cushioning effect. The teeth were coated and then vertically inserted in 2.5 cm × 2.5 cm × 2.5 cm self-curing acrylic resin blocks (DPI RR, India). Once the samples were securely mounted, they were subjected to compressive loading using a universal testing machine (Lloyd LR 30 K, Fareham, England). The machine used a spherical point placed in the middle of each molar's occlusal surface to provide a vertical compressive stress at a regulated rate of 1 mm/min. The force needed to fracture each molar was calculated in Newton (N)

Statistical Analysis:

SPSS program Version 20 (IBM SPSS Statistics Inc., Chicago, Illinois, USA) was used to perform the statistical analysis. Descriptive statistics, including mean and standard deviation, were calculated for each group, followed by an analysis of variance (ANOVA) to determine overall significance. To identify certain intergroup differences, post-hoc analysis was performed.

Result:

The comparison of fracture resistance among different groups revealed statistically significant differences ($F = 27.729$, $p < 0.001$). Group 1 (negative control, intact teeth) exhibited the highest mean fracture resistance (694.4 ± 60.49 N), whereas Group 2 (positive control, teeth with untreated strip perforation) showed a substantial reduction in fracture resistance (273.9 ± 96.18 N), confirming the detrimental effect of strip perforation on tooth strength. Among the tested restorative materials, Bio-C (Group 5) demonstrated the highest fracture resistance (685.2 ± 89.18 N), closely approximating the values observed in the negative control group. Biodentine (450.5 ± 143.15 N) and Mineral Trioxide Aggregate (452.3 ± 126.62 N) exhibited similar fracture resistance values, which were significantly higher than the positive control but lower than Bio-C.

Post-hoc analysis demonstrated significant differences in fracture resistance between groups. Group 1 (negative control) had significantly higher fracture resistance than Group 2 (positive control) (mean difference = 420.50 N, $p = 0.001$), confirming the negative impact of strip perforation. Group 5 (Bio-C) showed significantly higher fracture resistance than Group 3 (Biodentine) (mean difference = 234.70 N, $p < 0.001$) and Group 4 (MTA) (mean difference = 232.90 N, $p < 0.001$). No significant difference was observed between Biodentine and MTA ($p = 1.0$, NS). Group 1 and Group 5 had comparable fracture resistance (mean difference = 9.2 N, $p = 1.0$, NS), indicating Bio-C's effectiveness in restoring structural integrity.

Table 1: Comparison of effect of different root repair materials on fracture resistance of teeth with simulated strip perforation:

Material	Fracture resistance (N)	
	Mean	SD
Group 1 (negative control)	694.4	60.49

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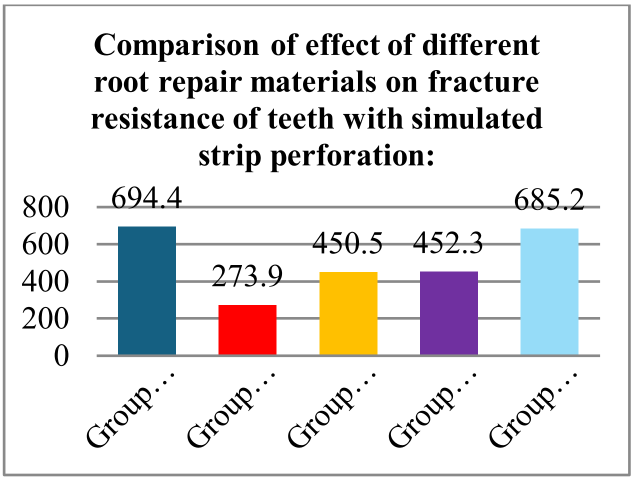
Group 2 (Positive control)	273.9	96.18
Group 3 Biodentine	450.5	143.15
Group 4 MTA	452.3	126.62
Group 5 Bio - C	685.2	89.18
F value, p value	F=27.729, p<0.001**	

Graph 1: Comparison of effect of different root repair materials on fracture resistance of teeth with simulated strip perforation



Discussion

Perforations are considered significant complications in dental practice and present various diagnostic and management challenges. (9) Perforations occur primarily through these three possible mechanisms: procedural errors occurring during root canal treatment or post-space preparation, (10,11) resorptive processes and caries. (12) Most perforations result from procedural errors. (13,14) During endodontic therapy, root perforations occur 3.85% of the time, with SPs accounting for 2.3% of these cases. (15)

Errors during access preparation and inappropriate use of instruments like Gates-Glidden drills can result in strip perforation, a type of root perforation that happens in the coronal third of the root canal, close to the furcation area. (16) On curved roots, like the mesial roots of mandibular molars, this perforation occurs. (17) In the mesial roots of mandibular molars, the mean dentine thickness 2 mm below the furcation varies between 0.78 and 1.27 mm, indicating areas that are prone to perforation, according to Zhou G. *et al.* (2020). In order to achieve standardization, SP was mimicked using a Gates Glidden drill No. 3 in the distal surface of the coronal third (3 mm below furcation) of the mesial root of mandibular molars. (18)

For obturation, molars were placed in a moist sponge to mimic the periapical resistance found in clinical conditions and to aid in the application of repair materials. A thin coating of polyether impression material was also applied to the apical third of all molar roots in order to protect the extracted molars from temperature changes while the acrylic resin was setting and to mimic the periodontal membrane in clinical settings. (15)

The fracture resistance test can be performed in two ways, either by separating the crown from the root as in some studies (19) or by keeping the crowns together with the roots. (20) Crowns were preserved in this study for two reasons. Firstly, accessing the perforation site from the access cavity is challenging, making it difficult to repair with the appropriate material, which is a common issue that specialists encounter in these cases. Secondly, establishing a force application model that accurately replicates masticatory forces in the mouth is essential, as the force is applied in a crown-to-apex direction. A universal loading machine was used for this purpose because of its ease of availability and low cost.

The analysis revealed significant variation in fracture resistance among different groups (Table-1), emphasizing the influence of strip perforation and the material used. Specifically, untreated strip perforations showed the least fracture resistance compared to negative control and treatment groups. These results underscore the reinforcing ability of different root repair materials in clinical practice, safeguarding against tooth loss and protecting the periodontium.

As the reference point for comparison, Group 1 (negative control), which represented complete teeth without perforation, had the maximum fracture resistance (694.4 N). This finding reinforces the structural integrity of unaltered teeth, demonstrating the natural strength of dentin and surrounding structures. The significantly higher resistance in this group compared to perforated and treated groups emphasizes the importance of preserving tooth structure during endodontic procedures.

The primary advantage of Biodentine as a furcation repair material is its ability to create a reliable seal even in the presence of moisture and blood. Biodentine has an alkaline pH of 12.5 and promotes periodontal ligament repair and cementogenesis, combined with a shorter setting time and a higher push-out bond strength. (21)

Mineral trioxide aggregate (MTA) is a widely recognized biocompatible material that promotes cementogenesis around perforation sites. It has been successfully used to repair perforations in various clinical scenarios. MTA needs moisture to set completely since it is hydrophilic. Therefore, Biodentine and MTA were used in this investigation. (22)

The analysis revealed that both Biodentine and MTA (450.5 N and 452.3 N, respectively) provided significantly greater resistance compared to the untreated perforation group (273.9 N), however, they were still less effective than the bioceramic repair group and intact teeth (694.4 N). These findings suggest that both Biodentine and MTA are viable options for strip perforation repair, offering biocompatibility and sealing ability while helping to preserve tooth integrity in clinical practice. Hassan FN *et al.* found that both ProRoot MTA and Biodentine performed equally well when used as furcation repair materials. (23)

Calcium silicates, calcium phosphate, calcium hydroxide, zirconium oxide, tantalum oxide, putties, and thickeners are the constituents of bioceramics. Furthermore, Bio-C Repair and Biodentine cement had larger concentrations of zirconium oxide, a radiopacifier, than ProRoot MTA. These materials are chemically stable, help enhance root fracture resistance, provide good radiopacity, have a high pH, are easy to handle, and do not undergo resorption. Furthermore, they interact with stem cells from periapical tissues, forming a biological seal and promoting the repair process. (7) Furthermore, Bio-C is a new ready-to-use bioceramic material introduced to endodontics in a threaded syringe, which offers handling and insertion improvements, collaborating with clinical practice and saving time, and so was used in this study.

Results showed that Group 5 (Bio-C) exhibited high fracture resistance comparable to the negative control (Group 1), with only a slight difference in mean values. In contrast, it demonstrated significantly higher fracture resistance than Group 2 (positive control), indicating its superior mechanical properties. Compared to Group 3 (Biodentine) and Group 4 (MTA), Bio-C showed a substantial increase in fracture resistance, suggesting enhanced durability and strength, reinforcing Bio-C's potential as a strong and reliable material in clinical applications.

Conclusion:

Strip perforation significantly reduces the fracture resistance of teeth, as demonstrated by the positive control group which showed the lowest strength. Among the materials tested, Bio-C exhibited the highest fracture resistance, closely matching that of intact teeth, making it the most effective for restoring structural integrity. Both Biodentine and MTA provided similar reinforcement capabilities, significantly improving strength. However, within limitations of study, small sample size, differences in tooth anatomy and operator technique may have affected results. Future studies should use larger samples, control access preparation and explore newer bioceramic materials in order to further improve treatment outcomes.

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