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ORIGINAL RESEARCH

Fracture resistance of primary molars after pulpotomy procedure using mineral trioxide aggregate or Biodentine

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Abstract

In this study, the effect of mineral trioxide aggregate (MTA) and Biodentine on the resistance to fracture of pulpotomized primary molars was evaluated. 75 primary molars were divided into 2 control groups (positive and negative) and 3 experimental groups with 15 teeth each. No treatment was applied to the teeth in the negative control group. In the teeth in the positive control group, pulpotomy cavities were performed, but not filled. In the teeth in the experimental group, pulpotomy cavities were performed, and filled as follows. Group 3: mineral trioxide aggregate + glass ionomer cement (GIC); Group 4: Biodentine + GIC and Group 5: zinc oxide-eugenol + GIC. Final restorations in teeth in all experimental groups were completed with composite filling material. 75 teeth were then subjected to fracture resistance testing. Obtained data were analyzed statistically. Sorting by fracture resistance; Group1 > Group 4 > Group 3 = Group 5 > Group 2 ($p < 0.05$). Restorable fracture type was predominant in experimental groups ($p < 0.05$). The use of Biodentine in teeth undergoing pulpotomy in primary teeth can be preferred as a suitable base material to increase resistance to fracture.

Keywords

Biodentine; MTA; Primary teeth; Pulpotomy

1. Introduction

Primary teeth, which act as space maintainer for permanent teeth, stimulate the vertical development of the jaws with chewing movements, and contribute to the nutrition, growth and development of the child, are also important in terms of phonation and aesthetics [1]. Early loss of primary teeth can cause undesirable conditions such as decreased chewing function, loss of space, malocclusion, speech disorders, psychological disorders and atypical tongue habits. For this reason, these problems are prevented by treating the decayed primary teeth and helping them to maintain their functions in the oral cavity until the eruption time of the permanent teeth [2].

In deeply carious primary teeth, pulpotomy is one of the treatment options applied in cases where the pulp is exposed during the removing of the caries but the root pulp is healthy and maintains its healing capacity. It is the process of removing the crown pulp affected by caries and inflamation, and covering the remaining healthy root pulp with a capping agent that will protect the vitality of the pulp or ensure its fixation [3–5]. It has been shown that the success of treatment in primary tooth pulpotomy depends on the age of the child, the severity of the inflammation in the crown and root pulp, the degree of root resorption, the technique used and the quality of the pulpotomy material, the characteristics of temporary or permanent restorations, the observation period and the experience of the physician [6, 7]. Improper restorations after pulpotomy treatment cause coronal microleakage, which is one of the factors that play a role in the failure of the treatment [8]. For this reason, it is recommended that the physical properties of the teeth be restored with a strong material in order to prevent the post-operative crown fractures and microleakage that may occur in primary teeth where increased fragility and excessive substance loss are observed after pulpotomy treatment [9, 10]. Tricalcium silicate materials are widely used in pulpotomy treatments. Among these materials, mineral trioxide aggregate (MTA) and biodentine are frequently used because they have been found successful in many clinical studies [4, 11, 12].

This study aimed to compare the effect of using MTA and Biodentine as base materials on the fracture resistance (FR) of pulpotomized primary molars.

2. Materials and methods

Based on the findings of a previous study [13], according to the power calculation results, the sample size for each group should be at least 15 (power 0.90, effect size = 0.862 and significance level $\alpha = 0.05$).

2.1 Preparation of teeth

In this study, first primary lower molars with occlusal caries not exceeding one-third of the intercuspal distance extracted due to periapical pathology and preventive orthodontic treatment (teeth without caries) were used. Teeth had belonged to children aged 4 to 6 years and their physiological root resorption did not exceed 1/3. Teeth were examined under an operating microscope to detect the presence of any cracks or fractures and stored in distilled water until the start of the experiment. To ensure standardization by incorporating similar sized teeth into the study, the buccal and lingual dimensions of the crown (height and width) were measured by a digital caliper with 0.01 mm accuracy. Fifteen teeth without caries served as the negative control group (Group 1) and received no treatment. The remaining 60 teeth were prepared using diamond fissure burs (Diatech, Coltene Whaledent, Altstatten, Switzerland) with 1-mm diameter and 4-mm height, and high-speed handpiece underwater and air spray. Following removal of the pulp chamber roof, a mesio-occluso-distal (MOD) cavity was prepared in such a way that the isthmus width of the occlusal cavity was two-thirds of the intercuspal distance, and the gingival floor in mesial and distal cavities was terminated at 1-mm distance from the cemento-enamel junction. Pulp chamber was thoroughly cleaned with a spoon excavator to remove pulp tissue, washed with normal saline and dried with an air spray. Fifteen of these teeth were used in the positive control group (Group 2) and no restoration was made to these teeth. Then, 45 teeth were divided into three experimental groups, as described below.

2.2 Experimental groups

Group 3: White MTA (Angelus, Londrina, PR, Brazil) was placed up to the middle of the pulp chamber, and the remaining part of the pulp chamber was filled with glass ionomer cement (GIC) (Fuji II LC®; GC, Tokyo, Japan).

Group 4: Biodentine (Septodont, Saint Maur des Fosse's, France) was placed on the teeth in this group up to the middle of the pulp chamber. GIC was placed in the remaining part of the pulp chamber.

Group 5: Zinc oxide eugenol (ZOE) (Caulk-Dentsply, Milford, DE, USA) was placed up to the middle of the pulp chamber and the remaining part of the pulp chamber was filled with GIC.

In all experimental groups, final restorations were completed using composite resin filling material (Filtek Z550; 3 M ESPE, St. Paul, MN, USA) (Fig. 1).

After the photopolymerization processes of the composite resin filling material were completed, polishing processes were performed using soflex discs (3M ESPE) followed by polishing rubbers. The teeth were mounted in autopolymerizing acrylic resin at 1-mm distance from their cemento-enamel-junction. Teeth were then stored in distilled water at 37 °C for 24 h, after which thermo-cycling aging was conducted for 5000 cycles (5 °C/55 °C) with a dwell time of 30 s and a transfer time of 10 s. The teeth were then subjected to chewing simulation. A total of 250,000 cycles were applied in an L-shaped direction of chewing simulation at 0.5 mm horizontal, 0.4 mm vertical, chewing frequency 1.6–1.7 Hz and 50 N force. The samples were placed on the lower part of the a universal test machine (Instron Corp, Canton, MA, USA) and a steel tip with a diameter of 4 mm was fixed on the upper moving part of the device. Fracture strength testing was carried out by applying a continuously increasing force at a speed of 0.5 mm/min parallel to the long axis of the tooth at the point corresponding to the central fossa of the teeth, except for the positive control group, in which the force was applied to the middle of the bucco-lingual width. Fracture types were classified as restorable or unrestorable. As "restorable" when the fracture line is above the acrylic resin (level of simulated bone) (Fig. 2A) and when the fracture line extended below the acrylic resin, it was classified as "unrestorable" (Fig. 2B) [14].

Data were statistically analyzed using one-way analysis of variance (ANOVA) and Tukey *post-hoc* tests. Fracture types were analyzed by chi-square test. All statistical analyzes were performed with SPSS version 20.0 for Windows (SPSS Inc., Chicago, IL, USA), and the significance level was set at $p < 0.05$.

3. Results

Table 1 shows means and standard deviation of the FR values for the groups. The highest FR was observed in Group 1, which comprised teeth without any preparation ($p < 0.05$). Group 2 (positive control) had the lowest FR values ($p < 0.05$). The FR values among the other groups were as follows: Group 3 = Group 5 < Group 4 ($p < 0.05$). When the fracture types of the experimental groups were examined, the most frequent failure type was restorable. Moreover, there was no difference between experimental groups when considering fracture types ($p < 0.05$).

4. Discussion

Following pulpotomy, teeth are more susceptible to fracture (compared to healthy pulp). The reason for this is the presence of extended caries and the removal of extensive tooth structure during pulpotomy cavity preparation [15]. This increases cusp deflection and the risk of cusp fracture during chewing function [17]. Therefore, it is essential to use restorative materials that support the remaining tooth structure following the pulpotomy treatment.

Reviewing the pediatric dentistry literature, it is clear there are few studies evaluating the FR of pulpotomy teeth [13, 17]. Moreover, there is no study comparing the effect of base (intraorifice barrier) materials on the FR of pulpotomized teeth. Roghanizad and Jones [18] introduced the concept of an intracoronal barrier to prevent coronal leakage in endodontically treated teeth. Nagas *et al.* [19], also stated that intraorifice barriers can be used under final restorations to provide resistance against forces that cause vertical fractures in teeth. An intraorifice barrier material or pulpotomy materials such as MTA or Biodentine is also used in pulpotomized teeth. Placement of these materials is important in terms of protecting the health of the pulp tissue in the root, preventing microleakage, and supporting the teeth against fracture.

Removal of the roof of the pulp chamber during pulpotomy procedure considerably reduces the support for these teeth

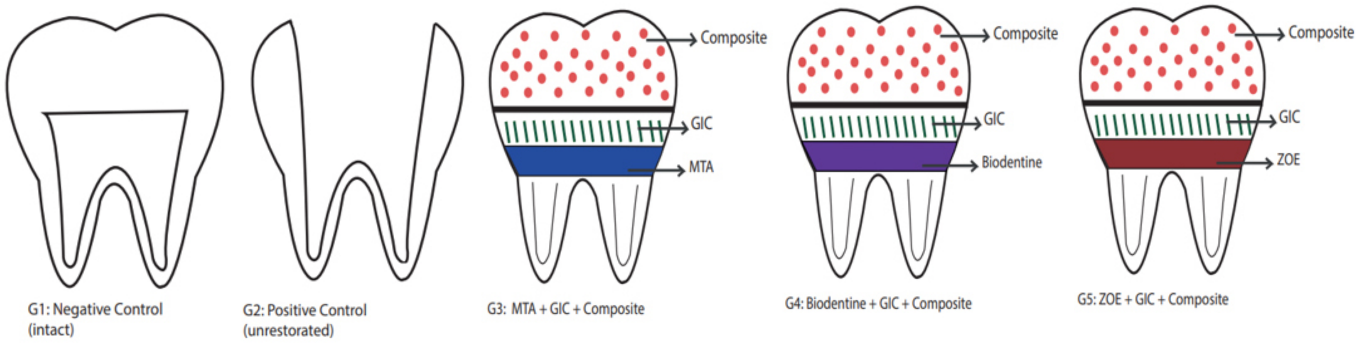

FIGURE 1. Schematic illustration of the groups. MTA: mineral trioxide aggregate; GIC: glass ionomer cement; ZOE: Zinc oxide eugenol.

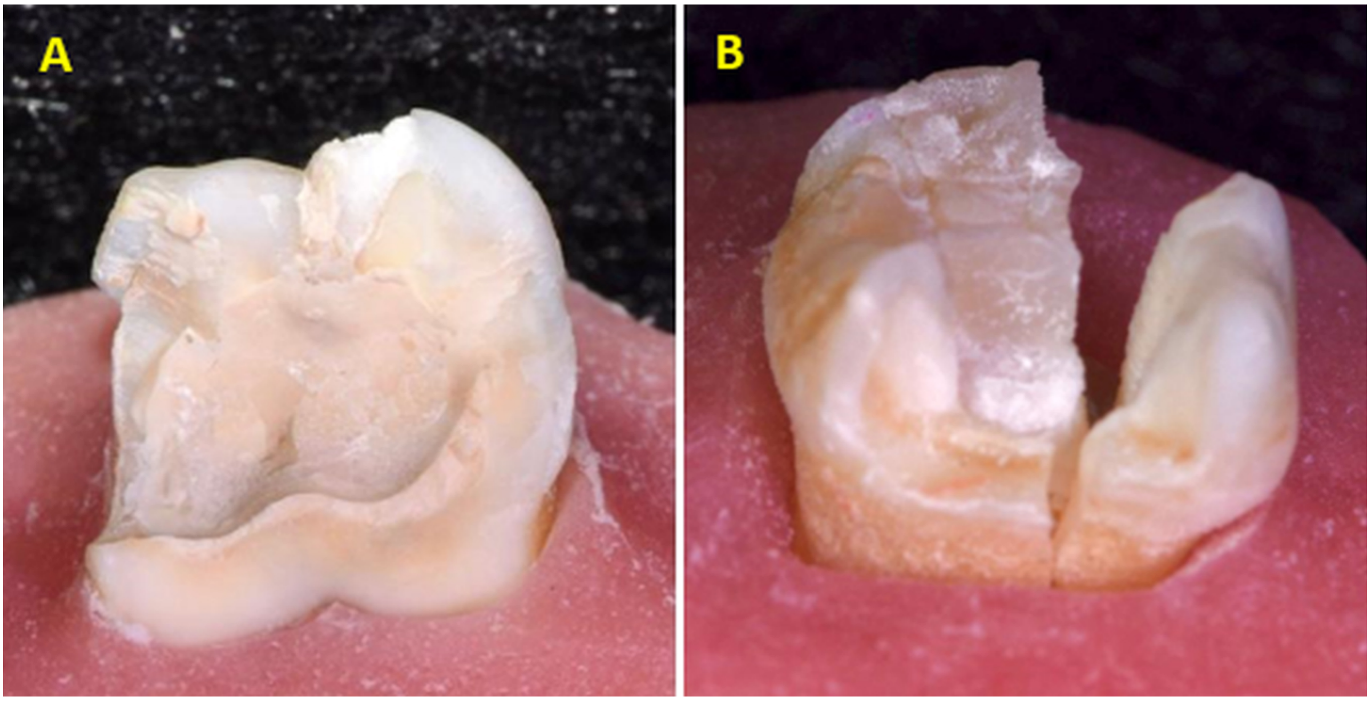

FIGURE 2. The samples of restorable/unrestorable fractures. (A) Restorable fracture; (B) Unrestorable fracture.

TABLE 1. Fracture resistance values and fracture type of the groups.

Groups (n = 15 for each group)	Mean ± SD (newton)	Fracture type	
		Restorable	Unrestorable
Negative control	624.13 ± 142.3^{A}		
Positive control	179.26 ± 45.2^{B}		
ZOE + GIC + Composite	312.50 ± 84.7^{C}	8^{a}	7
MTA + GIC + Composite	334.17 ± 71.4^{C}	13^{b}	2
Biodentine + GIC + Composite	496.36 ± 125.1^{D}	12^{b}	3

MTA: mineral trioxide aggregate; GIC: glass ionomer cement; ZOE: Zinc oxide eugenol; SD: Standard Deviation. Different superscript letters show a statistically significant difference ($p < 0.05$).

against chewing forces. Therefore, it is important that the materials to be placed both in the pulp chamber (as intraorifice material) and in the crown cavity are of a type that will protect the teeth against fracture [20–22]. The current study compared the effect on the FR of primary teeth of two different tricalcium silicate materials used an intraorifice barrier material during pulpotomy.

In studies investigating the effect of dental materials on the FR of teeth, the occlusal loading method during the test is important as it may affect the results. In many studies testing the FR of teeth, FR was tested by applying a vertical force to the center of the occlusal surface [23, 24]. In the current study, the fracture test was likewise performed by applying a vertical force. Nonetheless, because teeth will also be exposed to horizontal forces in the oral environment [21], this should be considered as a limitation of studies testing FR. In the current study, the effect of temperature changes and continuous chewing in the mouth was also simulated by exposing the teeth to the chewing simulator and thermo-cycler device.

In the present study, the FR of the pulpotomized teeth was lower than that of the negative control group. This may be associated with loss of tooth structure in pulpotomized teeth. This result is in line with previous studies which demonstrated that the FR of the teeth decreased after cavity preparation [15, 25]. Moreover, based on the results of the current study, the type of material used as intracoronal barrier material during pulpotomy procedure affected the FR of the teeth. In the present study, the increased force required to fracture teeth in Biodentine group relative to the other experimental groups could be explained by the smaller particle size and uniform components of Biodentine, which affects the adhesion of material into dentinal tubules [26]. Another possibility for this result may be that the compressive strength of Biodentine is higher than MTA and ZOE [27]. It has been stated that compressive strength is an indicator of strength of the material [28]. Furthermore, compressive strength of the material is important when used in clinical situations, such as vital pulp therapy and coronal barriers [29].

Considering the fracture types, the most frequent type was restorable in all experimental groups. Moreover, in Biodentine and MTA groups, the number of restorable fracture was much greater than that of unrestorable fracture, unlike ZOE group. This finding may be due to the fact that Biodentine and MTA can withstand large amounts of stress before transmitting the load to the root.

In this study, the applied force to evaluate the FR was applied parallel to the long axis of the teeth. This may be a major limitation of the present study because in clinical conditions, chewing forces are more complex, and loads and forces can be directed in different directions. Therefore, the results of this *in-vitro* study should be interpreted with caution because it would be impossible to simulate all oral conditions. Future laboratory studies are needed to evaluate the effect of different restoration protocols on the FR of primary molar teeth.

5. Conclusions

The FR of primary molar teeth can differ according to the base material used for the pulpotomy procedure.

AVAILABILITY OF DATA AND MATERIALS

Not applicable.

AUTHOR CONTRIBUTIONS

GT—designed the research study; wrote the manuscript. GT and HST—performed the research; analyzed the data. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The study protocol was approved by the Ethics Committee of Erciyes University Faculty of Medicine (approval number: 2022/780).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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