Atatürk Üniv Diş Hek Fak Derg (*J Dent Fac Atatürk Uni*)
Cilt:30, Sayı:4, Yıl: 2020, Sayfa: 564-70

Araştırma/ Research Article

FRACTURE RESISTANCE OF THE PRIMARY SECOND MOLARS PULPOTOMIZED BY VARIOUS AGENTS: AN IN-VITRO STUDY

ÇEŞİTLİ MATERYALLERLE PULPOTOMİ YAPILMIŞ İKİNCİ SÜT AZI DİŞLERİNİN KIRILMA DAYANIMLARI: İN-VİTRO BİR ÇALIŞMA

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Makale Kodu/Article code: 4241
Makale Gönderilme tarihi: 05.12.2019
Kabul Tarihi: 13.07.2020
DOI : *10.17567/ataunidfd.768626*

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ABSTRACT

Aim: The aim of this study was to evaluate the effect of various pulpotomy materials on the fracture resistance of pulpotomized primary second molars.
Materials and Methods: Hundred extracted primary second molars were randomly divided into five groups as follows: Control group (had no treatment), Zinc oxide-eugenol group (pulpotomized with zinc oxide eugenol), ProRoot MTA group (pulpotomized with ProRoot MTA), RetroMTA group (pulpotomized with RetroMTA), and Biodentine group (pulpotomized with Biodentine). The pulpotomized teeth were restored with compomer resin. All samples were then subjected to fracture resistance test using a universal testing machine. Data were analyzed using one-way ANOVA followed by post hoc Tukey's test. The level of significance was accepted at $p<0.05$.
Results: Control group had the highest fracture resistance value (1191.57 ± 121.09 N) and Zinc oxide-eugenol group had the lowest fracture resistance value (510.87±135.00). There was statistically significant difference between fracture resistances of the groups ($p<0.001$). The difference between Zinc oxide-eugenol group and RetroMTA group; Zinc oxide-eugenol group and ProRoot MTA group; ProRoot MTA group and Biodentine group was not statistically significant ($p>0.05$). However, Biodentine group showed significantly higher fracture resistance as compared to Zinc oxide-eugenol group and RetroMTA group ($p<0.05$).
Conclusions: The fracture resistance of primary second molars pulpotomized with ProRoot MTA and Biodentine was higher compared to the teeth pulpotomized with zinc oxide eugenol and RetroMTA.
Key words: pulpotomy, tooth deciduous, fracture resistance, compomers

ÖZ

Amaç: Bu çalışmanın amacı, farklı tipteki pulpotomi materyallerinin pulpotomi yapılmış süt azı dişlerinin kırılma dayanımları üzerindeki etkisini araştırmaktır.
Gereç ve Yöntem: Yüz adet çekilmiş süt ikinci azı dişi rastgele beş gruba ayrılmıştır: Kontrol grubu (herhangi bir tedavi yapılmamıştır), Çinko oksit öjenol grubu (çinko oksit ojenol ile pulpotomi yapılan), ProRoot MTA grubu (ProRoot MTA ile pulpotomi yapılan), RetroMTA grubu (RetroMTA ile pulpotomi yapılan), Biodentin grubu (Biodentin ile pulpotomi yapılan). Pulpotomi yapılan dişler, kompomer ile restore edilmiştir. Tüm örnekler universal test cihazı kullanılarak kırılma dayanımı testine tabi tutulmuştur. Veriler tek yönlü ANOVA ve post hoc Tukey testi kullanılarak analiz edilmiştir. Anlamlılık düzeyi $p <0,05$ olarak kabul edilmiştir.
Bulgular: Grupların kırılma dayanımları arasında istatistiksel olarak anlamlı fark bulunmuştur ($p<0,001$). Kırılma dayanımı kontrol grubunda, en yüksek bulunurken (1191,57±121,09 N), Çinko oksit öjenol grubunda en düşük bulunmuştur (510,87±135.00). Çinko oksit öjenol grubu ve RetroMTA grubu; Çinko oksit öjenol grubu ve ProRoot MTA grubu ; ProRoot MTA grubu ve Biodentin grubu arasındaki fark istatistiksel olarak anlamlı bulunmamıştır ($p> 0,05$). Bununla birlikte, Biodentine grubu, Çinko oksit öjenol grubu ve RetroMTA grubu ile karşılaştırıldığında kırılmaya karşı daha yüksek dayanım göstermiştir ($p <0,05$).
Sonuç: ProRoot MTA ve Biodentin ile pulpotomi tedavisi uygulanmış ikinci süt azı dişlerinin kırılma dayanımları, çinko oksit öjenol ve RetroMTA ile pulpotomize edilmiş dişlerden daha yüksektir.
Anahtar kelimeler: pulpotomi, süt dişi , kırılma dayanımı , kompomer.

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Kaynakça Bilgisi: Keleş S. Çeşitli materyallerle pulpotomi yapılmış ikinci süt azi dişlerinin kırılma dayanımları: in-vitro bir çalışma. Atatürk Üniv Diş Hek Fak Derg 2020; 30: 564-70.
Citation Information: *Keles S. Fracture Resistance of the primary second molars pulpotomized by various agents: An in-vitro study. J Dent Fac Atatürk Uni 2020; 30: 564-70.*

INTRODUCTION

Pulpotomy is a procedure for asymtomatic cariously exposed pulp with the presence of healthy radicular pulp in pediatric dentistry. The pulpotomy procedures involves covering pulp stamps with a pulp capping agent to promote healing or an agent to fix the underlying tissue[1].

Fracture resistance of the pulpotomized teeth may decrease due to the substance loss during cavity preparation[2]. Furthermore, the increase in the depth of the cavity plays a significant role in susceptibility of the pulpotomized primary molars to the fracture as floor of the pulp chamber constitutes the cavity floor and that leads unsupported cusps may be responsible for tooth fracture[3,4]. There are studies concluded that the presence of unsupported cusps increases the susceptibility of the tooth to the fracture[5,6]. Occlusal loads generate stress within the tooth. These forces are uniformly distributed along the occlusal surface, as well as inside the tooth in intact teeth. However, extensive cavity preparation alter the stress distribution and cause high tensile stresses on the pulpal floor. Finally, tensile stress resulted from repetitive occlusal load may lead to cuspal failure[7]. In such cases, the mechanical properties of pulpotomy material, which is placed in the pulp chamber, may affect the fracture resistance of the tooth.

Currently, there are various types of materials used for pulpotomy. Pulpotomy materials used (in chronological order, from the past to the present) are: Formocresol, ferric sulfate, calcium hydroxide, calcium-enriched mixture and mineral trioxide aggregate (MTA)[8,9].

MTA is usually preferred for the pulpotomy of the primary molars, due to its characteristics like high biocompatibility, high sealing capacity, alkaline pH, and antimicrobial properties, which increase the success rate of pulpotomies. However, it also has some disadvantages such as high cost, long setting time, tooth staining, and difficult handling properties[10]. In order to improve these disadvantages of MTA, other materials like Biodentine (BD), MTA Angelus, MTA Plus, OrtoMTA, RetroMTA, and Bioaggregate were developed[8].

Stainless steel crowns have been recommended for restoration of pulpotomized primary molars as they prevent coronal leakage and increase the success rate of the treatment[11]. However, stainless steel crowns require the removal of sound tissue and don't provide esthetic demands[12]. Compomer resins are commonly preferred by dentists, as they are easily to use in primary molar pulpotomies, preserve the hard tooth tissue, and provide satisfying esthetical outcomes[13,14].

Several researchers have conducted research on the fracture resistance of pulpotomized primary molars, which were restored with various restorative materials[15-19]. However, no study was conducted regarding the effect of different pulpotomy agents on the fracture resistance of pulpotomized primary molars. Therefore, the objective of this study was to evaluate the fracture resistance of the primary molars pulpotomized with various pulpotomy materials and restored with compomer resin. The null hypothesis of the study was that the type of pulpotomy materials had no effect on the fracture resistance of the pulpotomized primary second molars.

MATERIALS and METHODS

This in-vitro study was conducted in the Department of Pediatric Dentistry, Faculty of Dentistry, Aydin Adnan Menderes University, Aydin, Turkey during the period of January 2017-March 2017. The study was approved by the Ethics Committee of the Aydin Adnan Menderes University (Reference no: 2016/1019). Hundred carious primary second molar teeth that had been extracted due to physiological root resorption more than two third of the root length were collected. The teeth with cracks and extensive caries were excluded from the study. The soft tissue remnants were removed from the surface of the teeth with a periodontal scaler (H6/H7 Scaler; Hu-Friedy, Chicago, IL, USA), and they were stored in a sterile saline solution until the study date, no more than three months.

The mesiodistal and buccolingual dimensions of the teeth were measured with a digital caliper (Pella Inc., Redding, CA, USA). The mean mesiodistal and buccolingual dimension of the teeth was 10.45 mm and 9.33 mm respectively.

The teeth were inserted into the autopolymerizing acrylic resin (Palapress Vario; Heraeus Kulzer GmbH, Wehrheim, Germany) till 2 mm below the margin between the enamel and the dentin, with the help of a polyvinyl chloride cylinder-shaped box. The class II mesio-occlusal or disto-occlusal pulpotomy cavities with standard width and depth were prepared on the teeth with a water-cooled no.

330 high-speed bur by a single operator. The buccolingual width of the occlusal preparation was 2.5 mm and the depth of the occlusal preparation was 6 mm (from the pulpal floor to the cuspal tip). The buccolingual width of the proximal box was 4 mm and the gingival floor was located 2 mm coronal to the cementoenamel junction. The length of the proximal buccal and lingual walls was 4 mm (from the gingival floor to the cuspal tip)[16].

The final form of the pulp chamber was completed with a no. 6 carbide round bur and a low-speed handpiece. The teeth with pulpotomy cavities were randomized into five groups consisting of 20 teeth each.

Groups and pulpotomy procedures

The compositions and manufacturers of the materials used in the study are listed in Table 1. Figure 1 shows the steps of the sample preparation.

Table 1. Compositions and manufactures of the materials used in the study

Materials	Composition (%)	Lot Number	Manufacturer
ProRoot MTA	Calcium oxide (CaO) 44.2 Silicon dioxide (SiO_2) 21.2 Bismuth oxide (Bi_2O3_3) 16.1 Aluminium oxide (Al_2O_3) 1.9 Magnesium oxide (MgO) 1.4 Sulphur trioxide (SO_3) 0.6 Ferrous oxide (FeO) 0.4	13082005A	Dentsply/Tulsa Dental, Tulsa, OK, USA
Biodentine	Powder:Tricalcium silicate, dicalcium silicate, calcium oxide, calcium carbonate, zirconium oxide iron oxide Liquid:Calcium chloride, water soluble polymer, water.	B13821	Septodont, Saint Maur des Faussés, France
RetroMTA	Calcium carbonate ($CaCO_3$)60~80 Silicon dioxide (SiO_2) 5~15 Aluminium oxide (Al_2O_3) 5~10 Calcium zirconia complex 20~30	RM1502D07	BioMTA, Seoul, Korea
Cavex Zinc-Oxide Eugenol Cement	Powder: 99.4% ZnO, 0.6% Zn Liquid: Eugenol	150104	Cavex Holland BV, Haarlem, Netherlands
Dyract EXTRA	Urethane dimethacrylate, Carboxylic acid modified dimethacrylate,Triethyleneglycol dimethacrylate, Trimethacrylate resinDiethacrylate resins, Canphorquinone Ethyl-4 benzoate,Butylated hydroxy tolüeneUVstabiizer, Strontium-alumino-sodium-fluoro-phosphor-silicate glass, Highly dispersed silicon dioxide, Stronsium flüoride Ironoxide pigments and titanium oxide pigments	1503000502	Dentsply, DeTrey Konstanz, Germany
EQUIA Forte fill	Fluoro alimuno silicate glass	1502141	GC, Tokyo, Japan
Clearfil SE Bond	Primer: water, MDP, HEMA, hydrophilic dimethacrylates, camphoroquinone, Adhesive: MDP, Bis-GMA, HEMA, camphoroquinone hydrophobic dimethacrylate, N/N-diethanol p-toluidine bond, colloidal silica	000003	Kuraray Medical Inc., Kurashiki, Okayama, Japan

Control group (Group 1): No treatment.

Zinc oxide group (Group 2): Pulp chamber were capped with a layer of hard setting zinc oxide eugenol; adapted to 2 mm thickness using moist cotton pellets.

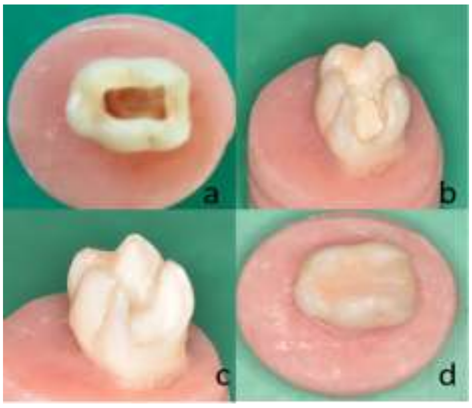

Figure 1. Steps of the sample preparation. a) standardized pulpotomy cavity, b) placement of the pulp dressing material, c) placement of the glass ionomer cement, d) restoration of the pulpotomized toot with compomer resin.

ProRoot MTA group (Group 3): ProRoot MTA with a thickness of 2 mm was inserted into the pulp chamber in accordance with the recommendations of the manufacturer. The mixture was delivered to the pulp chamber and was condensed lightly with a moistened cotton pellet.

RetroMTA group (Group 4): RetroMTA with a thickness of 2 mm was inserted into the pulp chamber according to the recommendations of the manufacturer. RetroMTA was allowed to set for 5 minutes.

Biodentine group (Group 5): Biodentine with a thickness of 2 mm was placed into the pulp chamber according to the recommendations of the manufacturer and was allowed to set for 12 minutes.

Restoration of the teeth

Glass ionomer base material (EQUIA Forte fill, GC, Tokyo, Japan) was applied with a 2 mm thickness, to all teeth. After the completion of the pulpotomy procedure, a metal matrix was placed around the tooth with the help of a Tofflemire retainer. A self-etch adhesive (Clearfil SE Bond, Kuraray Okayama, Japan) was applied to the cavities with a disposable microbrush according to the manufacturer's recommendations and light cured for ten seconds. The compomer resin was placed in increments of 2 mm and was light cured with a light-emitting diode light curing unit (Valo, Ultradent Products Inc., South Jordan, UT, USA) was used for 20 seconds. The finishing and polishing procedures were carried out with composite finishing bur and Sof-Lex (3M-ESPE Dental Products, St. Paul, MN, USA) polishing disk.

After the restorative procedures, samples were thermocycled to 5-55°C with a dwell time of 30 seconds for 1000 times. The Instron Universal Testing Machine (Lloyd LRX, Lloyd Instruments, Fareham, Hants, UK) was used to measure the forces required to fracture the teeth with a 3 mm round steel head to distribute the load. An increasing load force was applied with a crosshead speed of 1mm/min to the midpoint of the cavities on the occlusal surface of the teeth until a fracture occurred. The loads at the fracture were recorded in Newtons (N).

Statistical Analysis

G*Power 3.0.10 (Franz Faul, Christian-Albrechts-Universität, Kiel, Germany) software was used for determining the sample size. The results of the analysis showed that an 80% power with a significance level of 0.05 and moderate effect will be achieved for the five groups if the 20 teeth were evaluated in each group. All statistical analysis was performed using SPSS 20.0 statistical software package (SPSS, Chicago, IL, USA). The data were tested for normality by Shapiro-Wilk and Levene's test. Since the data were normally distrubuted, one-way ANOVA and post hoc Tukey's test used for statistical analysis at a significance level of p<0.05.

RESULTS

The mean fracture resistance values (±standard deviations) for all groups and significant differences among the groups are shown in Table 2. There were significant differences between the control group and study groups in terms of the fracture resistance (F=91.07, p<0.001). The highest fracture resistance value was obtained in the control group (1191.57±121.09 N) and the lowest was obtained in Zinc oxide-eugenol group (510.87±135.00 N). The teeth in the control group had the highest fracture resistance value and the difference with all other groups was statistically significant (p<0.001) (Figure 2).

Table 3 shows the intergroup comparisons of the fracture resistance values of the groups. The difference between the control group and the other groups was statistically significant in terms of fracture resistance (p<0.001). There was statistically significant difference between fracture resistance of the Zinc oxide-eugenol group and Biodentine group (p<0.001). Additionally, RetroMTA group had lower fracture resistance than the Biodentine group and the difference between the groups was statistically significant (p<0.05).

Table 2. Comparison of fracture resistance of the groups.

Groups	N	Mean (Newton/mm^2) ±SD	Minimum	Maximum	ANOVA
Control	20	1191.57±121.09	900.75	1400.80	F=91.07 p<**0.001***
Zinc oxide-eugenol	20	510.87±135.00	351.00	764.85	
ProRoot MTA	20	646.89±105.57	463.72	785.00	
RetRoMTA	20	590.00±96.49	366.00	731.91	
Biodentine	20	735.95±159.80	513.21	974.19	

The statistical evaluation was performed using one way ANOVA .*Statistically significant difference at p<0.05 value.

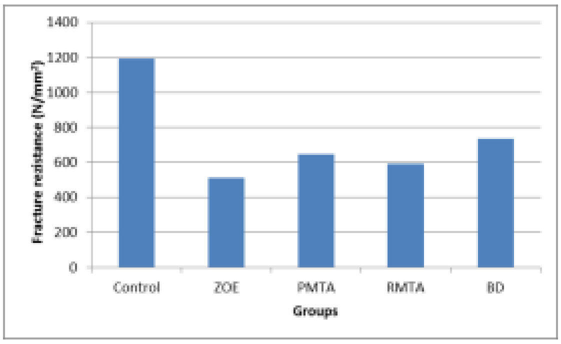

Figure 2. Mean fracture resistances of the groups (Abbreviations: **PMTA**:ProRoot MTA; **BD**:Biodentine; **RMTA**:RetRoMTA; **ZOE**: Zinc-oxide eugenol).

There was no statistically significant difference between Zinc oxide-eugenol group and ProRoot MTA group (p=0.06) and RetroMTA group (p=0.50). Moreover, there was no statistically significant difference between ProRoot MTA and RetroMTA group (p=0.80); ProRoot MTA and BD group (p=0.37), in terms of fracture resistance.

Table 3. Intergroup comparison of fracture resistance of the groups.

	Groups				
	Control	*Zinc oxide-eugenol*	*ProRoot MTA*	*RetRoMTA*	*Biodentine*
Control		***0.001****	***0.001****	***0.001****	***0.001****
Zinc oxide-eugenol			*0.06*	*0.50*	***0.001****
ProRoot MTA				*0.80*	*0.37*
RetRoMTA					***0.03****
Biodentine					

*The statistical evaluation was performed using post hoc Tukey test .*Statistically significant difference at p<0.05 value.*

DISCUSSION

This study evaluated the fracture resistance of the primary second molars, which were pulpotomized with various pulpotomy materials. Present study confirmed that the type of pulpotomy material had an impact on the fracture resistance of pulpotomized primary second molars. The highest bond strength was obtained in Biodentine and ProRoot MTA groups, following the control group in this study.

Previous studies mainly had focused on the effects of restoration materials on the fracture resistance of the pulpotomized primary molars[2,15-19]. However, in the literature there is no study which investigated the effect of the materials applied into the pulp chamber on the fracture resistance of the teeth.

Materials widely used for the pulpotomy procedure in pediatric dentistry have undergone a change from the past to the present. Although devitalization or preservation of the remaining pulp was targeted after the removal of the inflamed pulp in the past, nowadays, after the development of bio-inductive and biocompatible materials such as MTA and tricalcium silicate-based materials, regeneration of the remaining pulp is targeted[20]. MTA stimulates cytokine release from the bone cells and induces hard tissue formation and has a dentinogenic effect on the pulp. When the first time MTA was introduced in marketing, it had certain unfavourable features like high cost, long setting time, difficult implementation, and tooth staining[10]. RetroMTA is a newly developed hydraulic bioceramic material for vital pulp therapy. Compared with ProRoot MTA, RetroMTA has a shorter setting time, good handling properties, no cytotoxicity, setting reaction initiated by moisture, and greater washout resistance[8]. Biodentine is an another material that can be used as a base restorative cement with dentin-like properties similar to MTA for primary molar pulpotomy[5].

Kaup et al.[9] compared the physicochemical properties of ProRoot MTA and Biodentine, and showed that Biodentine has a higher Vickers micro-strength value and is superior to the alternatives as a substitution material. Furthermore, the shorter setting time of Biodentine is an advantage for clinical use.

In this study, the fracture resistance value was higher in Biodentine goup than ProRoot MTA group. However, the difference between ProRoot MTA and Biodentine group was not statistically significant. While the fracture resistance was lower in RetroMTA group and zinc oxide eugenol group, there was no statistically significant difference between these groups regarding the fracture resistance. In the literature, there is no study compare the fracture resistance levels of primary molars pulpotomized with various agents, therefore we were not able to compare our study with others.

There are several alternative materials for the restoration of pulpotomized primary molars in pediatric dentistry. Compomer resins, composite resins, glass ionomer cement, stainless steel crowns, amalgam, ormocers, and zirconium crowns are among these alternatives. Compomer resins are the usually preferred alternative, due to their easy implementation, supporting features regarding the natural tooth tissue, favorable esthetics due to similarity with tooth color, and flouride releasing properties[21-22]. Nainar et al.[21], reported that compomer resins were a favorable alternative to amalgam and stainless steel crowns in cases of class II cavities.

El-Kalla and Garcia-Godoy[17] stated that the adhesive and restorative procedures necessary for the use of composite resins protected the natural tooth tissue and normal contact points, thereby rendering them superior to stainless steel crowns in pulpotomized teeth. Passi et al.[23], restored the pulpotomized teeth with different restorative materials and found that ormocers had the highest fracture resistance and the glass ionomers had the lowest. Mohammad et al.[2], reported that nanocomposite materials have higher fracture resistance compared to the glass ionomer and cermet cements in pulpotomized teeth. Contrary to these studies, Malekafzali et al.[18], reported that fracture resistance of pulpotomized teeth that had been restored with glass ionomer cement, amalgam, and composite resins had similar fracture resistance, but lower than the intact teeth. In our study, we used the same compomer resin and dentin bonding agent for restoration of the pulpotomized teeth.

Carious primary second molars that had been extracted due to physiological root resorption more than two third of the root length were used in this study[24]. There might be some differences in tooth anatomy, enamel and dentin thickness, pulp chamber geometry, and external dimensions of the crowns. The mesiodistal and buccolingual widths of the teeth crowns were measured and the teeth with similar size were included in the study to standardize the size of pulpotomy cavities. In addition, glass ionomer base material and compomer resin with equal thickness were used as restorative materials.

There are only a few studies evaluated the bite force in children. Kamegai et al.[25], conducted a study on 2594 school-age children and found that the average bite force among children in the age group of 6 to 11 years was 330.5 N in girls and 374.4 N in boys. In other studies, the mean value of maximum bite force has been reported between 151.9 and 374.4 N[26,27]. In this study, mean value of fracture resistance determined in all groups were beyond the reported maximum bite forces in children.

According to the results of this study, the type of the pulpotomy material had an impact on the fracture resistance of the pulpotomized primary second molars. Thus, the null hypothesis of this study was rejected. The *in-vitro* design of this study might be considered as a limitation of the study. There is a need for further *in-vivo* studies evaluate the effect of pulpotomy material on the fracture resistance of the primary molars restored with compomer resin.

CONCLUSION

Biodentine and ProRoot MTA increased the fracture resistance of the pulpotomized primary second molars. These materials may be preferable in primary second molar pulpotomy to increase their longevity in the mouth.

Acknowledgements
This project was supported by the Scientific Research Project Fund of Aydin Adnan Menderes University under the project number DHF-15006.
Conflict of Interest
No potential conflict of interest relevant to this article was reported.

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