ORİJİNAL ARAŞTIRMA ORIGINAL RESEARCH

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Root Reinforcement with an Injectable Pozzolan Based Sealer in Combination with RetroMTA® in Simulated Immature Roots

Bir Enjektabl Pozzolan Bazlı Kanal Patının RetroMTA® ile Kombinasyonu ile Kök Güçlendirilmesi

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ABSTRACT Objective: The aim of this study was to evaluate the effect of an injectable pozzolan-based root canal sealer in combination with RetroMTA on fracture resistance of simulated immature teeth. **Material and Methods:** Fifty-five mandibular premolars were used. Roots were cut from the cemento-enamel junction and access cavities were prepared. Working lengths were determined and the canals were instrumented using Reciproc system up to R40 instrument. Peeso reamers (No. 1-6) were used, and the Peeso reamer no. 6 was stepped out from the apex to simulate an incompletely formed root. Specimens were distributed into five groups according to the filling techniques (n=11): Group 1: Negative control, Group 2: EndoSeal MTA, Group 3: RetroMTA, Group 4: Apical plug with RetroMTA + backfill with EndoSeal MTA, Group 5: Apical plug with RetroMTA + backfill with thermoplasticized gutta-percha and EndoSeal MTA. All roots were embedded in the acrylic blocks. A vertical fracture compression test was applied with a universal testing machine at a crosshead speed of 1 mm/min. The fracture loads were recorded for each tooth, and statistical interpretations were made by using SPSS 20.0 (α=0.05). **Results:** There are statistically significant differences among the groups (p<0.05). The mean values of Group 2 showed the highest results (835±278.53 N). The lowest mean values were in Group 1 (507.663±151.732 N). **Conclusions:** Considering the results of our study, it can be said that filling the root canals with MTA products in immature teeth contributes positively to the fracture resistance of the roots.

Keywords: MTA; tooth fracture; simulated immature teeth; endodontics

ÖZET Amaç: Bu çalışmanın amacı, enjekte edilebilir bir pozzolan bazlı kök kanal patının, RetroMTA ile kombinasyon halinde simüle edilmiş apeksi açık dişlerin kırılma direncine etkisini değerlendirmektir. **Gereç ve Yöntemler:** Çalışmamızda 55 alt küçük azı diş kullanıldı. Dişlerin kronları ve kökleri mine sement birleşiminden ayrıldı ve kök kanal boşlukları şekillendirildi. Çalışma uzunlukları belirlenmiş ve kanallar Reciproc sistemi kullanılarak R40 alete kadar genişletildi. Apeksi açık dişleri simüle edebilmek için, Peeso no.6 ile köklerin dışına çıkıldı. Örnekler, doldurma tekniklerine göre beş gruba dağıtıldı (n = 11): Grup 1: Negatif kontrol, Grup 2: EndoSeal MTA, Grup 3: RetroMTA, Grup 4: RetroMTA+Apikal dolgu, EndoSeal MTA, Grup 5: Termoplastik gutta-percha ve EndoSeal MTA ile RetroMTA + apikal dolgu. Tüm kökler akrilik bloklara gömüldü. Üniversal test cihazı ile 1 mm /dak hızında kompresyon kırma testi uygulandı. Her diş için kırılma yükleri kaydedildi ve SPSS 20,0 (α=0,05) kullanılarak istatistiksel analizler yapıldı. **Bulgular:** Gruplar arasında istatistiksel olarak anlamlı farklılık olduğu tespit edildi (p<0,05). Grup 2'nin ortalama değerleri en yüksek sonuçları gösterdi (835±278,53 N). En düşük ortalama değerler Grup 1'de tespit edildi (507,663±151,732 N). **Sonuç:** Çalışmamızın sonuçları göz önüne alındığında immatür dişlerde kök kanallarının MTA içerikli ürünlerle doldurulmasının köklerin kırılma direncine olumlu yönde katkı sağladığı söylenebilir.

Anahtar Kelimeler: MTA; diş kırığı; simüle edilmiş immatür dişler; endodonti

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Dental trauma occurs often at 8-12 years-of-age. Traumatic tooth injuries generally result from pulp necrosis, and patients are frequently referred to dental clinics with open apices and infected root.[1] The endodontic treatment of these devitalized, immature teeth can become troublesome. The dentinal walls of these types of roots are often thin; thus, root fractures may occur, especially in the cervical root region.[2-4]

Historically, the treatment choice for immature root apices has been the calcium hydroxide ($Ca(OH)_2$) treatment, which is called apexification.[5,6] The success rate of this treatment has been found to be 79-96%.[7] However, researchers have suggested other treatment options because of the long waiting time involved in $Ca(OH)_2$ treatment with its multiple appointments, reduced patient tolerance, and root fracture.[8]

Currently, an apical plug with mineral trioxide aggregate (MTA), or regenerative endodontic treatment applied with MTA, is used instead of long-term $Ca(OH)_2$ treatments.[9-11] Performing an apical plug with MTA provides the fastest solution for immature root treatment. Some authors suggest the sealing whole root canal with MTA to obtain a primary monoblock structure, but it is still a matter of debate about which restorative material should be used for these teeth.[12]

Various calcium silicate (CaSi) based materials have been developed to improve MTA's chemical and physical properties. EndoSeal MTA (Maruchi; Wonju, Korea) is a pozzolan-based product that can also be used as a root canal sealer. Pozzolans are silica and aluminum materials that have no binding properties on their own or that have a very low binding capacity but can exhibit hydraulic binding when combined with calcium hydroxide in an aqueous medium in a fine grained state.[13] In addition, this material has a high washout resistance, is biocompatible, and has mineralization potential and odontogenic effect.[13-15]

In contrast, RetroMTA® (BioMTA; Seoul, Korea) is a hydraulic, bioceramic, endodontic material that does not include portland cement but does include hydraulic calcium zirconia as a radiopacifying agent. Owing to the hydraulic calcium zirconia, RetroMTA® does not show coloration, and, thus, it is suitable for aesthetic repair. The initial setting time of RetroMTA® in the moist environment of the oral cavity (approximally 150 sec.) is also an advantage.[16]

In the literature, there is lack of knowledge about the subject matter of the present study. The purpose of this study is to assess the effect of an injectable pozzolan-based root canal sealer combined with RetroMTA® on the fracture resistance of simulated immature teeth. The null hypothesis was that there were no differences among the root canal obturation techniques in terms of fracture resistance.

MATERIAL AND METHODS

After approval by the local ethics committee of Erciyes University, Kayseri, Turkey (Decision number: 2017/512), this study was carried out in accordance with the Helsinki Declaration Principles. For all removed teeth, patients were signed an informed consent form. 55 human mandibular premolar teeth with single and straight roots were choosen. To determine the single and straight canal morphologies, buccolingual and mesiodistal radiographs of the specimens were taken. An operating microscope (OPMI pico; Zeiss, Germany) was used for inspecting the teeth to confirm that they had no deformities, cracks, resorption, or caries.

The specimens were decoronated with slow speed diamond discs (IsoMet; Buehler, Lake Bluff, IL, USA) under water cooling to prepare a standard root length of 10 mm. The pulp tissue remnants were removed ultrasonically, and standard access cavities were performed. The patency of each root canal was controlled with a size 10 K-file (Dentsply Maillefer; Ballaigues, Switzerland), and the working length was determined to be 1 mm short of the apex and corresponded to 9 mm. The root canals were prepared with a Reciproc instrument (VDW; Munich, Germany; up to size R40) in "Reciproc all mode" using a VDW Silver endodontic motor (VDW; Munich, Germany). Irrigation was performed by 2 mL of 2.5% NaOCl solution using a 30 gauge needle after each instrument change. Peeso reamer drills (RelyX, 3M ESPE), up to size 6 (No.1-6), were used to enlarge each canal, and

the drills were stepped out 1 mm beyond the apex to simulate an immature root. To remove the smear layer it was used 2 mL of 17% ethylenediaminetetraacaetic acid (EDTA) for 1 minute. Final irrigation was performed using 10 mL of 5% NaOCl and 3 mL of distilled. Absorbent paper points were used to wipe the root canals. The specimens were distributed into five groups according to the root filling techniques (n = 11):

Group 1: The root canal was prepared but not filled (negative control group).

Group 2: The entire root canal space was filled with EndoSeal MTA.

Group 3: The entire root canal space was filled with RetroMTA®.

Group 4: A 4 mm thick apical plug was performed with RetroMTA®. Then, the remaining root canal space was backfilled with EndoSeal MTA.

Group 5: A 4 mm thick apical plug was performed with RetroMTA®. Then, the remaining root canal space was backfilled with EndoSeal MTA in combination with thermoplasticized gutta percha by using a BeeFill 2in1® device (VDW; München, Germany).

The root canal orifices were closed with a temporary filling material (Cavit G; 3M ESPE, Seefeld, Germany). After setting, to simulate the periodontal ligaments, a polyether impression material (Impregum F; 3M ESPE, St. Paul, MN, USA) was used to coat the surface, up to 8 mm from the apex of the root. The teeth were then embedded in plastic tubes filled with self-curing acrylic resin (Imicryl; Konya, Turkey), up to 8 mm from the apex. Next, the temporary filling materials were removed, and each acrylic mould was placed in a universal testing machine (Instron Corp; Canton, MA, USA) holding a 4 mm diameter round tip, which was placed in contact with the surface of the obturated root canal. The testing machine was moved vertically, with a crosshead speed of 1 mm/min, until a fracture occurred (Figure 1). The fracture load was then recorded.

All of the statistical analyses were performed using SPSS 20.0 (IBM Corporation Software Group; Armonk, NY, USA). The Shapiro-Wilk's test showed that the data were distributed normally; thus, a one-way ANOVA test was applied to the data. Because the Levene's variance homogeneity test failed, a Tamhane's T2 test was used for the post-hoc analyses ($\alpha = 0.05$).

RESULTS

The descriptive statistics of each group are provided in Table 1, and an error bar graph is shown in Figure 2. The highest fracture resistance values were found in Group 2 (835 ± 278.53 N), and the lowest values were found in Group 1 (507.663 ± 151.732 N). According to the statistical comparisons, there were statistically significant differences among groups ($p < 0.05$). Group 2 and Group 3 showed significantly higher fracture resistance values than the negative control group and Group 5 ($p < 0.05$). There were no other statistically significant differences among the groups ($p > 0.05$).

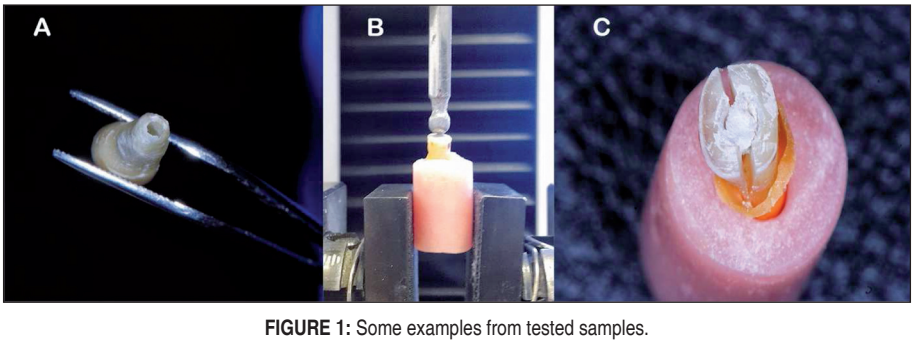

FIGURE 1: Some examples from tested samples.

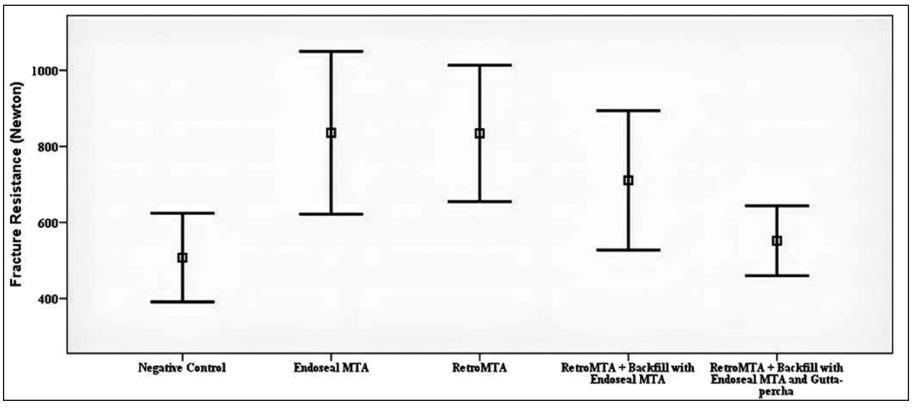

FIGURE 2: Error Bar Grafic.

TABLE 1: Descriptive statistics of the tested groups.

	Mean ± Std. Dev. (Newton)	Minimum	Maximum
Group 1[a]	507.663± 151.732	356.70	800.40
Group 2[b]	835.97 ± 278.53	310.19	1156.21
Group 3[b]	834.23 ± 233.28	537.15	1215.73
Group 4[a,b]	710.78 ± 219.18	448.19	1088.93
Group 5[a]	551.74 ± 119.48	428.90	824.15

*Std.Dev. (Standard deviation).

*Significantly different groups are shown with different superscript letters.

DISCUSSION

In the present study, mandibular premolar roots were used because of their circular cross-sections in the mid to apical region, which result in uniform distribution of the load to fracture. They also simulated the clinical situation better where chewing forces were at maximum.[17] Immature roots are more prone to fracture than mature roots because they have thin dentinal walls with undeveloped peritubular and intertubular dentin.[18] To mimic the open apex formation, each canal was enlarged with Peeso reamer drills, up to size 6 (No.1-6), and the drills were stepped out 1 mm beyond the apex. This is a practical method that was previously used in the literature; therefore, this technique was preferred in this study.[19,20]

Restoring immature teeth is a challenging procedure in endodontics. Choosing a single-visit-apexification using a MTA apical plug provides some advantages, such as fewer appointments, immediate apical seal, and strengthened root structures, which long-term $CaOH_2$ treatment weaken in contrast.[21-23] In the one-visit-apical-plug technique, the selection of the material to be used is important because of the proximity of the vital periapical tissues. MTA is a biocompatible material for periapex; however, it has poor handling properties, a prolonged setting time, and coronal discoloration effects.[24] Thus, research has been carried out to develop materials that will overcome these disadvantages. RetroMTA® and EndoSeal MTA are two such relatively recent materials developed according to conventional MTA.

In their study, Hatibovic-Kofman et al. investigated the fracture resistances of teeth with immature formation and found that MTA was superior when compared to $CaOH_2$ after a one year period. They based this conclusion on MTA's tissue inhibitor of metalloproteinase 2 (TIMP-2) expression in the dentin matrix and how it eliminates the degenerative effects of matrix metalloproteinase-2 and -14 (MMP-2 and -14).[25] In the present study, specimens were kept in a SBF solution for five weeks. The contamination of PBS-like solution and MTA-based endodontic cements can cause hydroxyl apatite-like layers between the dentin and cement, and this can result in chemical bonding to the dentin.[26,27] This formation may provide greater vertical root fracture resistance to the tested teeth.

According to Mozynska et al., RetroMTA® is a biocompatible and hydraulic bioceramic material that cause less discoloration on tooth.[28] Because of this feature, it can be used in anterior teeth that have open apices. According to the findings of this study,

RetroMTA® backfilling showed greater strengthening effects than the gutta percha backfilling. Furthermore, researchers have been exploring and suggesting various alternatives to gutta-percha filling, and EndoSeal MTA is a pozzolan-based material that is suggested for use as a root canal obturation material with or without gutta-percha. EndoSeal MTA has advantages like biocompatibility, odontogenic effect, potential biomineralization, and high washout resistance. In this study, the EndoSeal MTA without gutta-percha usage resulted in higher fracture resistance values than with the gutta-percha usage.

In a previous study, Belli et al. reported that the formation of a primary monoblock unit within the root canal can prevent root fractures. It is well known that CaSi-based materials like MTA can bind chemically to the dentinal walls and are able to create primary monoblocks in the root canal.[12,29] In the present study, CaSi-based materials (e.g., EndoSeal MTA or RetroMTA®) were used solely to form a monoblock sealing structure in Groups 2 and 3. Therefore, these results may be related to the monoblock effect.

In summary, the results of this study do not support the null hypothesis that fracture resistance would not vary between the different obturation techniques in immature roots; therefore, it was rejected.

CONCLUSION

The fracture resistance of root canals filled entirely with MTA-based root canal materials are higher than other groups, which can be connected to their ability to form monoblocks and to bind to the dentin. Filling the entire root canal with a MTA-based material to strengthen the roots of the teeth where apexification is not complete may cause the patient to use the tooth longer, but the strengthening of the tooth root is not the only criterion for this; other factors such as leakage should be considered. Future studies are needed to investigate the effects of the properties of MTA-based materials on the fracture resistance and the strengthening of the roots.

Source of Finance

During this study, no financial or spiritual support was received neither from any pharmaceutical company that has a direct connection with the research subject, nor from a company that provides or produces medical instruments and materials which may negatively affect the evaluation process of this study.

Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

Idea/Concept: *Tuğrul Aslan;* ***Design:*** *Tuğrul Aslan;* ***Control/Supervision:*** *Gülter Devrim Kakı;* ***Data Collection and/or Processing:*** *Tuğrul Aslan;* ***Analysis and/or Interpretation:*** *Tuğrul Aslan;* ***Literature Review:*** *Gülter Devrim Kakı;* ***Writing the Article:*** *Gülter Devrim Kakı;* ***References and Fundings:****Tuğrul Aslan, Gülter Devrim Kakı.*

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