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Comparative Evaluation of the Push-Out Bond Strength of Root-End Filling Materials by Using Different Condensation Methods

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Abstract

BACKGROUND/AIMS: This study aims to evaluate effect of the application of ultrasonic devices in the simulation models with the push-out test and compare with traditional methods during transfer of bioactive materials to the root canal.

MATERIALS AND METHODS: In our study 60 extracted human single-root mandibular premolars without caries, root resorption, or fractures were used. The samples were standardized and divided into four sections randomly. Samples were embedded to alginate impression material for simulating the periapical tissue. Group 1; 4 mm of the apical of teeth were obturated with mineral trioxide aggregate (MTA) (Angelus, Brazil) and condensed by plugger. Group 2; 4 mm of the apical of teeth were obturated with MTA and condensed by plugger and ultrasonic activation. Group 3; 4 mm of the apical of teeth were obturated with Biodentine (Septodont, France) and condensed by plugger. Group 4; 4 mm of the apical of teeth were obturated with Biodentine and condensed by plugger and ultrasonic activation. The push-out test was performed using a universal testing machine.

RESULTS: According to result of this study, ultrasonic activation groups (groups 2 and 4) of bond strength values were better than plugger condensation groups (groups 1 and 3) of bond strength values ($p<0.05$).

CONCLUSION: The bond strength of bioactive materials used in single visit apexification is an important factor for the success of the treatment in the future. According to the results of this study, the application of materials by ultrasonic activation shows higher bond strength than hand condensation in the application of MTA and Biodentine to the apical region of immature teeth.

Keywords: Bioactive materials, bond strength, push-out test

INTRODUCTION

Trauma or deep caries in the immature tooth can result in pulpal necrosis with incomplete root formation. Encountering immature teeth causes clinical difficulties in root canal treatment. Apexification is mandatory to obtain an adequate root canal filling since no apical terminus of the root and thin fragile walls are observed in the root canals. Calcium hydroxide [$Ca(OH)_2$] material has been used in the apexification procedure for many years to induce apical closure.[1] Andreasen et al.[2] stated that the strength of immature teeth decreased by 50% after a 1-year follow-up of calcium hydroxide application compared to the control group.

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Mineral Trioxide Aggregate (MTA, MTA Angelus, Londrina, Brazil) material is produced by Torabinejad for use in root-end filling and perforations.[3] MTA is the most preferred material in the single session apexification method due to its strong physical, chemical, and clinical properties in the apical region, being bacteriostatic, establishing a good plug, dimensional stability, biocompatibility, and sealing.[4] However, there are also some disadvantages such as application difficulty, long curing time, and apical leakage that may occur until the curing is completed.[5]

Therefore, newly developed calcium silicate-based materials, as alternative fast-curing materials, have been examined to increase clinical success. Biodentine (Septodont, Saint Maur des Fosse, Cedex, France) is a fast curing (~10–12 minutes) calcium silicate-based material. Several *in vitro* studies and case reports suggest the use of Biodentine as an alternative to MTA due to its similar sealing ability, biocompatibility, mineralized tissue formation, superior hydroxyapatite apposition when exposed to tissue fluids, and stimulating the healing ability of periapical tissue.[6]

The mixture and application method of the root end closure material is a factor affecting the success of the dental material. It was suggested that ultrasonic activation could facilitate the compressed air escape and allow the rearrangement of material particles. However, there are discussions about the effectiveness of this method.[7] In a study examining the effect of both mixing and ultrasonic activation techniques of MTA on marginal adaptation, no difference was observed between hand-applied and ultrasonic condensation methods. Moreover, Aguiar et al.[8] reported that materials placed using coronal ultrasonic activation had shown better adaptation. In the study comparing the stress distributions of Biodentine and MTA as a root-end closure material, it was stated that there was no difference between the two materials. Because there was no study examining the effect of condensation of the root-end closure materials using ultrasonic activation on bond strength, this study was conducted on this subject. This study evaluates the effect of the application using ultrasonic devices in the simulation models by the push-out test, as well as, to compare with traditional methods in terms of the transfer of bioactive materials to the root canal. The null hypothesis is that ultrasonic activation affects bond strength and interfacial adaptation of bioactive materials.

MATERIALS AND METHODS

In this study, 60 extracted human single-root mandibular premolars were used that without caries, root resorption, or fractures. After removing the tissue residues on the teeth, each tooth was stored in 0.1% thymol solution at room temperature until they were used in the study. Teeth crowns were removed from the cervical enamel junction using diamond disks under water cooling, to obtain a standard root length of 13 mm from the apex. Root canal preparation protocol defined by Lawley et al.[9] was applied to the obtained samples. Root canals were instrumented with a #2 Peeso Reamer (Dentsply, Maillefer, Ballaigues, Switzerland) to the working length and then an open apex was prepared #8 (0.60) Profile Series (Dentsply, Maillefer, Ballaigues, Switzerland) 29.04 taper at the foramen retrogradely for sandglass shape. During preparation, root canals were rinsed with 2.5% NaOCl. A final rinse with 2 mL 2.5% NaOCl for 1 min, 2 mL 17% EDTA for 1 min, and 10 mL distilled water was performed. The canals were dried with paper points. Then, samples were divided into four sections randomly and for simulating the periapical tissue, the teeth were embedded to alginate impression material.

Group 1; 4 mm of the apical of teeth were obturated with MTA (Angelus, Londrina, PR, Brazil) according to manufacturer recommendations (mix 1 ladle of powder with 1 drop of distilled water for 30 seconds) and condensed by plugger (Dentsply, Maillefer, Ballaigues, Switzerland).

Group 2; 4 mm of the apical of teeth were obturated with MTA according to manufacturer recommendations and condensed by plugger and ultrasonic activation (Mini-Endo Unit, SybronEndo, Orange, CA).

Group 3; 4 mm of the apical of teeth were obturated with Biodentine (Septodont, France) according to manufacturer recommendations (Mix 1 capsule of powder with five drops of liquid for 30 seconds using vibratory mixing machine) and condensed by plugger.

Group 4; 4 mm of the apical of teeth were obturated with Biodentine according to manufacturer recommendations (Mix 1 capsule of powder with five drops of liquid for 30 seconds using vibratory mixing machine) and condensed by plugger and ultrasonic activation.

In Groups 2 and 4, a Mini-Endo ultrasonic unit (SybronEndo, Orange, CA) with a ball-like tip (File Adapter; Spartan) at 50% power was used to apply ultrasonic activation to #7 condensers to flow, settle and compact the MTA and Biodentine to root apex. Using by radiographs, the quality of the fillings evaluated. Specimens that cracks or canals inadequately filled were eliminated and switched by a new sample. After condensation procedure, moist cotton pellet had placed into teeth and coronal region was closure by using provisional filling materials. All samples were stored for 10 days at 37 ^{o}C and 100% humidity for materials set up.

The push-out test was applied using a universal testing machine (Lloyd Instruments, Fareham Hants, England). In this study, all samples had embedded acrylic resin, after it was setting, the resin block was divided from the metal meld and put in the cutting machine. 2 samples with 1 mm thickness were taken from middle of 4 mm apical section of teeth. To verify the thickness of the slices were measured using a digital caliper (Digimess, São Paulo, Brazil) with 0.01-mm accuracy. Under ×2 magnification, the sections that observed irregular cement thickness or voids were excluded from the study. Each dentin/resin material disc with root-end filling was set in the mechanical test machine (EMIC DL 2000), with a 5 kN load cell. (Figure 1) Progressive compression test was achieved with the power applied from coronal to apical at 1 mm/min speed, from the touch of the device tip to filling material displacement.[10-11]The cylindrical piece had 1.3 mm caliber and continued connection with sealer. After these measures the values were obtained in newton (N) and converted into MPa. The value attained was divided by the adherence surface area of root canal filling, calculated by a certain formula for explain the bond strength in megapascal (MPa).

$$Area = \pi(R1 + R2)\sqrt{(R1 - R2)^2 + h^2}$$

The area (mm^2) under the load was calculated from the cylinder lateral surface area formula: bonding area=2πrh, where "r" is the radius of the preparation circumference, and "h" is the thickness of the root slice (2.0 mm). Divided the load (N) into the bonding area (mm^2), the bond strength value in megapascals (MPa) was calculated. Data were statistically analyzed to Two-way ANOVA and post hoc Tukey's tests at significance level of 0.05.

RESULTS

The bond strength values (MPa) between groups are shown in Table 1. Group 4 had the highest bond strength value and there were no differences between Group 2 and 4 and Group 1 and 3 ($p>0.05$). Ultrasonic activation groups (Group 2 and Group 4) were better results than plugger condensation groups (Group 1 and Group 3).

DISCUSSION

Studies reported that marginal adaptation and bond strength are closely related to each other. Bioactive materials containing calcium silicate produce apatite-like structures and precipitate between calcium phosphate material and dentin, and dentin tubules. This molecular tag-like structure provides the formation and allows the formation of a hybrid layer on the interface.[12] In this study, materials were placed in the root canal by ultrasonic activation to strengthen the connection. Ultrasonic activation is provided by the conduction of micrometric acoustic energy. The acoustic energy generated by the ultrasonic device is transmitted to the material as a mechanical vibration to achieve better adaptation at the cement-dentin interface.[11-13] The MTA shows a good bond strength for facilitating the tooth to show resistance to masticatory forces.[14] The push-out mechanical test is used to assess the bond strength of root-end filling and post-core materials to the dentin. The push-out test is a suggested method that shows effective and consistent results.[15] Lawley et al.[9] examined the effect of MTA placed in the canal manually and using the ultrasonic device on root fracture formation. The authors reported that ultrasonic activation of MTA during obturation was more successful than manual condensation alone. Camilleri et al.[3] stated that the application of Biodentine into the root canal by ultrasonic activation increased the adaptation of the material on the root canal surface. Many clinical and laboratory studies have proven that the porosity of the material caused mechanical and physical problems.[16,17] In their study comparing the porosity of MTA at the end of hand condensation and ultrasonic activation, Rahimi et al.[18] observed less porosity in the ultrasonic method compared to the hand condensation method. These results are similar to the results

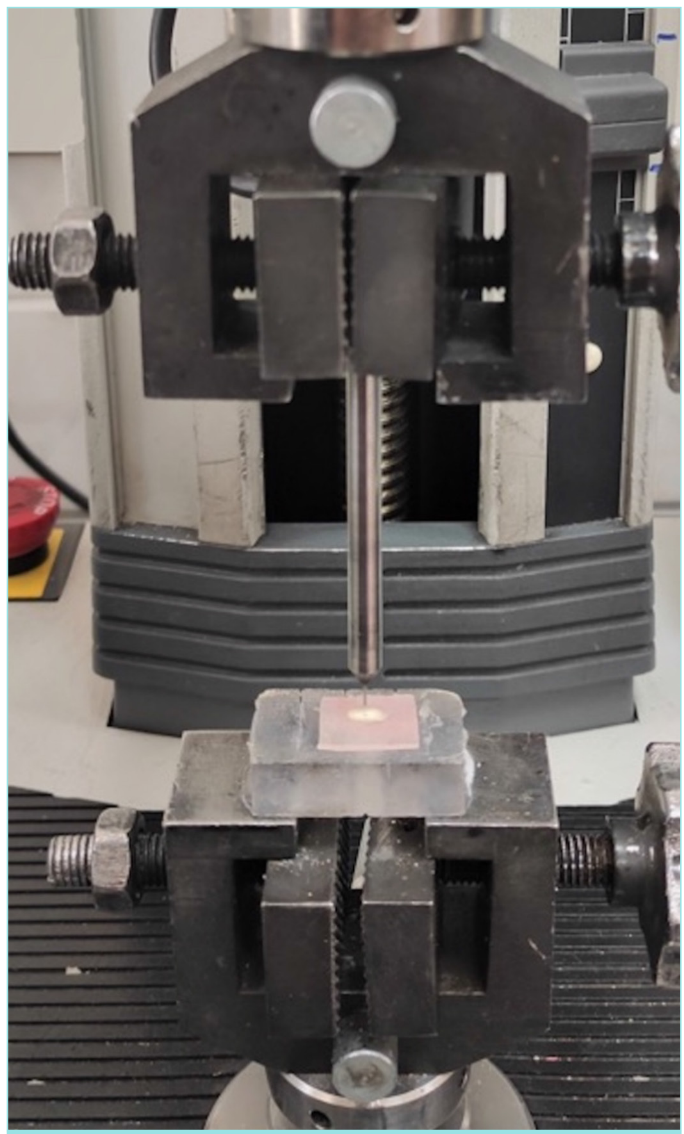

Figure 1. Illustration of PBS test of the specimens.
PBS: Push-out Bond Strength.

Table 1. Bond strength of values (MPa), mean ± standard deviation and number of slices			
Materials	**n**	**Bond strength (MPa)**	**Standard deviation**
Group 1 (MTA condensed with plugger)	30	14.25[a]	±1.36
Group 2 (MTA condensed with plugger and ultrasonic activation)	30	19.33[b]	±2.47
Group 3 (Biodentine condensed with plugger)	30	14.78[a]	±1.45
Group 4 (Biodentine condensed with plugger and ultrasonic activation)	30	21.36[b]	±2.66

*Different letters in the same column indicate statistically significant differences ($p<0.05$). MTA: mineral trioxide aggregate

of this study. Similarly, the application of MTA and Biodentine materials into the root canal by ultrasonic activation increased the bond strength in the groups using these materials in this study.

Moreover, the physical characteristics of the materials are other factors that affect the prognosis of the treatment. These characteristics depend on temperature, particle size, humidity, liquid/powder ratio, the quantity of air trapped in the mixture.[19] In previous studies, researchers stated that calcium silicate-based materials penetrate more easily into dentin tubules and exhibit higher bond strength due to their smaller particle size.[20] Biodentine contains less dicalcium silicate than MTA, thus, exhibited a more homogeneous structure that increased bond strength.[20,21] Torres et al.[22] evaluated the porosity of MTA and Biodentine and observed that MTA had a more porous structure than Biodentine in their study. They also stated that the porosity of the material could affect bond strength. Dawood et al.[23], Kaup et al.[24], and Natale et al.[11] reported that Biodentine showed higher hardness, elastic modulus, and flexural strength compared to MTA. In another study, Biodentine and MTA used for treating immature teeth did not result in any significant difference against the risk of root fracture resistance.[25] Similar to a study by Villat et al.[26], no difference was observed between the bond strength values of the hand-condensed MTA and Biodentine in this study. This result can be explained using different powder-liquid ratio in the mixture and may be due to the experimental differences in the studies. As a limitation of this study, mixing the MTA material manually may cause operational errors. This may be because factors such as powder-liquid ratio and the curing time cannot be standardized in the manual mixing method, also, the manual mixing method results in more air voids. However, Biodentine is mixed using an amalgam vibrator; thus, it provides the same standard conditions in each mixing. Also, it was reported to eliminate errors that may be caused by the operator.[27]

Another limitation of this study is the lack of periodontal ligament and bone structure that absorbs the forces applied to the teeth clinically and affects the distribution of these forces.[28] Note that the results obtained using the alginate model to simulate clinical conditions do not directly reflect the clinical settings.

CONCLUSION

The bond strength of bioactive materials used in single visit apexification is an important factor for the success of the treatment in the future. According to the results of this study, the application of materials by ultrasonic activation shows higher bond strength than hand condensation in the application of MTA and Biodentine to the apical region of immature teeth.

MAIN POINTS

- Single visit apexification procedures are applied to teeth incomplete root development.
- Ultrasonic activation is an effective application in the condensation of bioactive materials.
- The bond strength of bioactive materials used in apexification is an important factor for the success of the treatment in the future.

ETHICS

Ethics Committee Approval: The ethical approval was obtained from the Ethics Committee of the Hatay Mustafa Kemal University (Ref no: 2017/18).

Informed Consent: N/A.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: P.T., S.S., A.Ö., F.S.S., B.Ç., Design: P.T., S.S., A.Ö., F.S.S., B.Ç., Data Collection and/or Processing: P.T., S.S., A.Ö., F.S.S., B.Ç., Analysis and/or Interpretation: P.T., S.S., A.Ö., F.S.S., B.Ç., Literature Search: P.T., S.S., A.Ö., F.S.S., B.Ç., Writing: P.T., S.S., A.Ö., F.S.S., B.Ç., Critical Review: P.T., S.S., A.Ö., F.S.S., B.Ç.

DISCLOSURES

Conflict of Interest: The authors declare no conflict of interest.

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