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Original Research

Micro-Computed Tomographic Evaluation of the Sealing Quality and Bond Strength of Different MTA Apical Plugs

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ABSTRACT

Objective: This study aimed to compared the effects of different placement techniques to the sealing quality of mineral trioxide aggregate (MTA) apical plugs at apexification technique by micro-computed tomography (micro-CT) and compared the bond strength to root dentin of an injectable MTA (BIOfactor MTA), MTA Angelus and AH Plus.

Methods: Sixty dentinal root slices were obtained from 20 maxillary centrals.A canal-like hole was drilled into each slices canal space.The samples were divided into 3 groups (n=20).All materials were delivered into the holes. Push-out tests were performed and fracture types were analysed with a strereomicroscope. In the second part of the study,72 maxillary central teeth with standardised artificial divergent open apex were divided into 4 groups; MTA Angelus and BIOfactor MTA were mixed mechanically, and introduced to form 4 mm thick apical plugs by hand condensation or indirect-ultrasonic activation for 10 seconds. Incidence of external voids between dentin walls and MTA apical plugs and porosity inside MTA were determined by volumetric analysis with micro computerized tomography (micro-CT).

Results: No significantly difference was found between the bond strength values of the materials (p:0.370; $p>0.05$).The external voids and porous voids are similar in both MTA (p: 0.685; $p>0.05$). When indirect-ultrasonic activation was applied,there was significantly less porosity statistically than hand condensation (p:0.00; $p<0.05$).

Conclusion: MTA Angelus and BIOfactor MTA materials showed similar results in terms of bond strength to root dentin, fracture types, adaptation to dentin walls and structural porosity rate. Both MTA materials showed less structural porosity when placed by indirect ultrasonic activation technique compared to manual condensation.

Keywords: Apical plug, Micro CT, MTA, Push-out

INTRODUCTION

Torabinejad developed MTA as a root-end filling material in 1993 and it has started to be used to create an apical barrier in single-visit apexification treatments owing to its superior biocompatibility and sealing ability. MTA is also used in many other dental treatments, such as vital pulp treatments, root-end filling material, and perforation and resorption repair, because of its advantageous properties, such as its outstanding sealing ability, superior biocompatibility, marginal adaptation, and tissue regeneration [1–3].

However, despite all its advantages, it is difficult to fill a narrow root canal with MTA. The use of a lentulo spiral and MTA carrier has been tried, but applying MTA to a narrow root apex can still be difficult and time-consuming. In addition, although MTA is condensed with hand tools, its inability to penetrate the dentinal tubules adequately, its sandy feature, and the fact that it cannot be removed from the canal after hardening make it impossible to use in a complex canal system and retreatment [4]. An insufficient water-to-powder ratio and insufficient mixing also prevent MTA from adapting to the canal wall [5].

To increase the canal wall adaptation of MTA, placement techniques have been suggested using direct and indirect ultrasonic activation methods [6,7]. Especially when used to form an apical plug, different materials have been sought due to problems such as the short working time during application to the tooth, the difficulty of transport and placement in the cavity, and insufficient and heterogeneous condensation in the apical region [8,9]. Recently, BIOfactor MTA (Imicryl Dental, Konya, Türkiye), has been used for pulpotomy, pulp capping, root perforation repairs, root-end filling, and apical plug procedures. BIOfactor MTA can be prepared in different fluency depending on the treatment method. According to the manufacturer, BIOfactor MTA does not cause tooth discoloration and has a stronger seal, shorter curing time, easier handling properties, and finer powder for faster hydration [10,11].

MTA placement in teeth with divergent open apex is known to be a technique-sensitive procedure, and the most successful placement technique for MTA material has not yet been defined [12]. In addition, there is little information about the relationship between the placement technique of MTA applied as an apical plug and the quality of the plug.

Main Points;

- MTA is a material used in dentistry in many areas such as direct pulp capping, regeneration, apexification and repair of perforation and resorption.
- Thanks to its advantages such as ease of mixing and application to the tooth, injectable MTA shortens the procedure time and reduces the risk of contamination.
- The bond strength of injectable MTA (BIOfactor MTA) to root dentin was found to be similar to that of MTA Angelus. When the fracture types after bond strength were analysed, the results of both MTA materials were similar and the most common type of fracture was adhesive failure.
- In MTA placement with indirect ultrasonic activation, porosities within the MTA and between the MTA and the dentin wall were found to be statistically less than in MTA placement with hand condensation.

This study aims to evaluate the effect of different application techniques on the sealing property and porosity of the apical plugs of two different MTA materials (MTA Angelus and BIOfactor MTA) using microcomputed tomographic imaging using micro-CT. In addition, the bond strength of these materials to root dentin is evaluated by comparing the materials with an epoxy resin-based root canal filling paste (AH Plus) using the push-out bond strength test method.

The research hypotheses were that there is no significant difference between the two MTA materials when used as apical plugs in terms of adaptation and structural porosity ratios of cements to dentin and their bond strength to root dentin.

MATERIALS AND METHODS

Ethical approval was obtained from Selçuk University Clinical Research Ethics Committee (2017-09/14). Using G*Power 3.0.10 statistical software (v.3.1.9.7), a minimum sample size of 72 (minimum 18 for each group) for micro CT analysis and a minimum sample size of 60 (minimum 20 for each group) for thrust ligament strength were calculated for an effect size of 0.4 and 80% statistical power at a significance level (α) of 0.05. A total of 92 upper incisors extracted for orthodontic or periodontal reasons— 20 for the push-out test and 72 for the micro-CT— were included in the study. To remove the attachments on the root surfaces of the teeth, a periodontal curette, a rotating rubber cap, and pumice-water slurry were used. The teeth, which were kept in 5.25% sodium hypochlorite (NaOCl) for 1 hour for disinfection, were kept in physiological saline until use.

Push-out Test

Sample Preparation

The surface-cleaned 20 teeth were sectioned from the cementoenamel junction (CEJ) with a diamond saw. The obtained tooth roots were fixed on acrylic blocks, which were placed in a precision sectioning saw (IsoMet 1000; Buehler, Lake Bluff, NY, USA). Three horizontal cross sections (1 ± 0.05 mm thick) were obtained from the upper and middle third segments by sectioning vertically to the long axis, using a diamond disk under water cooling (125 x 0.35 x 12.7 mm; Buehler Ltd). In total, 60 root slices were drilled with 1.3 mm cylindrical carbide burr

(Dentsply Maillefer, SA CH-1338, Ballaigues, Switzerland) to obtain standardized cavities in the root canal space. All samples were kept in a 2.5% NaOCl solution for 15 minutes and then bidistilled water for 1 minute. To remove the smear layer, the samples were immersed in 17% EDTA (Titriplex@III, Merck, Darmstadt, Germany) for 3 minutes, bidistilled water for 1 minute, 2.5% NaOCl for 1 minute, and finally bidistilled water for 1 minute. The holes were dried with absorbent paper points. The specimens were randomly divided into three groups (n = 20). MTA Angelus (Soluçoes Odontologicas, Londrina, Brazil), BIOfactor MTA (Imicryl, Konya), and a control group using AH Plus (Dentsply DeTrey, Konstanz, Germany) were prepared according to the manufacturer's instructions (Table 1) and applied into the cavities with gentle vibration**.** Finally, specimens were stored in contact with a phosphate-buffered saline solution (PBS) (pH 7.2) at 37 °C and 100% humidity for 7 days.

Push-out Test

To evaluate the push-out bond strength, a 1 mm diameter cylindrical stainless steel piston tip in a universal testing machine (Instron, Norwood, MA, USA) was placed on the tested material without touching the root dentin wall. A 1 mm/min speed load was applied on fillings only in an apical coronal direction until dislocation occurred. The maximum load at filling failure, noted in newtons, was converted to megapascals (MPa) by using the following formula: newtons/(2π rh), where π is the constant 3.14, r is the radius of the intra-radicular space, and h is the height of section in millimeters (Figure 1).

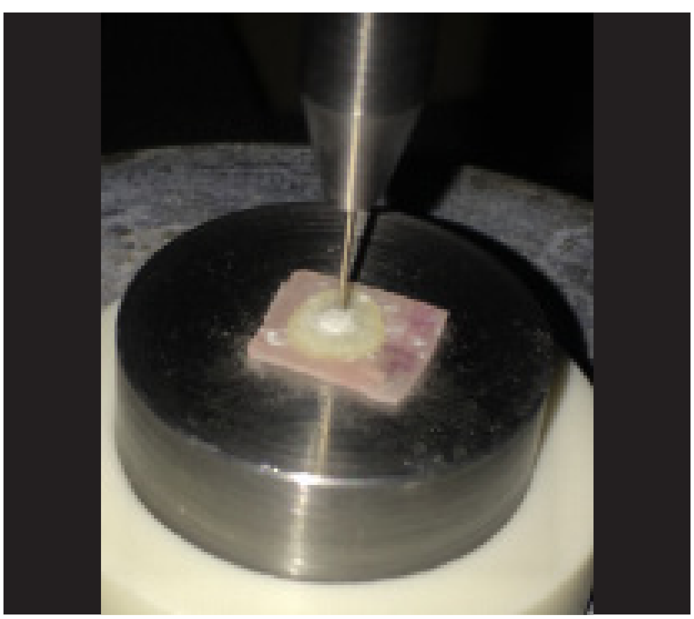

Figure 1. One sample was positioned to undergo the push-out test.

Stereomicroscopy Analysis

After the push-out test, the coronal and apical faces of all sections were analyzed by a single examiner under a stereomicroscope (SZ-PT Olympus, Osaka, Japan) in x25. The types of failure observed in the sections were divided into three categories in terms of breaking type: adhesive failure between MTA and dentin interface, cohesive failure within the MTA, and mixed failure, a combination of the two.

Micro-CT Test

Sample Preparation

Surface cleaned 72 teeth were cut from the CEJ with a diamond saw so that 13 mm long standard tooth samples were prepared. The apical 2 mm section was cut with a diamond fissure burr (Maillefer, SA CH-1338, Ballaigues, Switzerland) to eliminate and standardize the presence of any apical delta under water cooling. The canal length was determined visually with stainless steel #15 K mesh files (Mani, Tochigi, Japan) 0.5 mm shorter than the apex. A protaper rotary system (Dentsply, Maillefer, Ballaigues, Switzerland) of F1–F5 files (Dentsply, Tulsa Dental, Tulsa, OK) was used for the cleaning and biomechanical preparation of the root canals of the prepared teeth. The canals were irrigated with 2 mL of saline and 2 mL of 2.5% NaOCl at each file change. Retrograde preparation for simulation of open apex, using 1-4 no. Gates-Glidden burrs (Mani, Tochigi, Japan) was conducted. During the procedure, tooth roots were maintained with saline-impregnated gauze. The divergent shape of the apices of the sample teeth whose biomechanical preparation processes were completed was checked with digital radiographs. Prepared teeth were kept in PBS until use. The 72 teeth were divided into four study groups (n = 18 each) as follows:

Group 1: MTA Angelus + hand condensation (Angelus-Manuel)

Group 2: BIOfactor MTA + hand condensation (BIOfactor-Manuel)

Group 3: MTA Angelus + indirect ultrasonic activation (Angelus-Ultrasonic)

Group 4: BIOfactor MTA + indirect ultrasonic activation (BIOfactor-Ultrasonic)

Mechanical Mixing

For standardization, 1 g of powdered MTA and 0.34 g of distilled water from all groups were mixed in amalgam capsules (Ruby Cap II, Istanbul, Türkiye) for 30 seconds at 4500 rpm in an amalgamator (YDM Amalgamator Hangzhou Yinya New Materials Co., Ltd., China), according to the in vitro model applied by Sisli and Ozbas [13].

Table 1. Compositions of tested materials and instructions for use

Product and manufacturer	Lot Number	Composition	Instructions for use
MTA Angelus (Angelus Industria de Produtos Odontologicos, Londrina, Brazil)	17897	Powder: tricalcium silicate, dicalcium silicate, tricalcium aluminate, calcium oxide, bismuth oxide Liquid: distilled water	Mix 1 scoop of powder with 1 drop of distilled water for 30 seconds
BIOfactor MTA (Imicryl Dental, Konya, Türkiye)	18201	Powder: tricalcium silicate, dicalcium silicate, tricalcium aluminate, calcium sulfate hemihydrate, and ytterbium oxide for radiopacity. Liquid: 0.5%–3% hydrosoluble carboxylated polymer, demineralized water	Mix 3 scoops of powder with 1 drop of liquid until having a homogeneous consistency
AH-Plus (Dentsply DeTrey, Konstanz, Germany)	1511000326	Base: epoxy resin, calsium tungstat, zirkonium oxside, silicate, ferric oxide pigments Catalyst: amines, calsium tungstat, zirkonium oxside, silicate, silikone fluids	Using a metal spatula, mix the two pastes in equal volumes (1:1) until having a homogeneous consistency

Hand Condensation

MTA was delivered using an MTA carrier (MAP; Produits Dentaires, Vevey, Switzerland) to the root canals. MTA was placed conventionally with size 3 and 4 pluggers until the apical plug was 4 mm.

Indirect Ultrasonic Activation

During the transfer of MTA into the canal in layers with MAP, indirect ultrasonic activation was applied by placing a size-1 plugger in the center of the material while avoiding contact with the walls, and a CPR-1 ultrasonic tip (Ellipson type; Satelec, Acteon group, Merignac, France) was placed in contact with the plugger. The piezoelectric ultrasonic unit (Suprasson P5 Newtron, Acteon Group, Mount Laurel, NJ) was then activated for 10 seconds at 25 kHz. All steps were repeated until the thickness of the MTA plug was 4 mm.

The thickness and density of the MTA apical plug were checked radiographically. Moist cotton pellets and a 3 mm temporary restorative material (Cavit, 3M ESPE, D-8031 Seefeld, Germany) were placed in the coronal part of the canal to ensure complete hardening of the MTA and kept in a 100% humidity environment at 37 °C. Temporary fillings placed on the sample teeth were removed in all study groups after 3 days. The root canal filling of the sample teeth was completed with the lateral condensation technique using AH Plus, a resin-based canal filling paste, and gutta percha (Diadent, Korea). The glass ionomer cement placed into access cavity. All samples were kept at 37 °C at 100% humidity for 7 days.

Micro-CT Imaging and Analysis

A new generation micro-CT device, the SkyScan 1272 (SkyScan 1272, Kontich, Belgium) was used, along with N-recon software (SkyScan 2010, Aartselaar, Belgium) and CTAn software (CT Analyser, SkyScan, Aartselaar, Belgium). Samples with root canal fillings were carried out by adjusting the X-ray source of the device at 80 kV and 120 µA power; exposure lasted 3.1 seconds with a 0.5 mm thick Al filter, 0.4° rotation, and 180° vertical rotation angle. As a result of the scans, 537 tagged images of each sample were obtained in TIFF format. By combining these raw images with the N-recon program, approximately 600 cross-sections in BMP format were obtained, allowing the internal structure of each sample to be examined. The obtained sections were transferred to the CTAn program. The volumetric ratios of the spaces' external voids between the MTA and the dentinal walls, the porosity inside the MTA of the samples prepared using the Region of Interests, and the threshold data determined by the CTAn program were calculated separately.

Statistical Analysis

IBM SPSS statistics software 15.0 was employed to analyze the tested group.

Statistical Analysis of Push-Out Test

According to the Kolmogorov-Smirnov test result, the data showed normal distribution (p-value = 0.820 > 0.05). A one-way Analysis of Variance (ANOVA) test was applied for the MPa values of the three groups. Statistical difference was shown at the 0.05 significance level.

Statistical Analysis of Micro-CT Testing

According to the Kolmogorov-Smirnov test result, the data showed normal distribution (p-value = 0.820 > 0.05). An Independent-Sample T-test was used for the porosity values of the groups. Statistical difference was shown at the 0.05 significance level.

RESULTS

Results of Push-Out Test

Table 2 shows the mean and standard deviations for each group. No significantly difference was found between the bond strength values according to the results of the one-way ANOVA test (p = 0.370 > 0.05). Under the stereomicroscope, cohesive- and mixed-type failures were seen more and at equal rates than the adhesive-type failure in the MTA Angelus and BIOfactor MTA groups (Figure 1). The most cohesive-type failures were observed in the AH Plus group (Table 3).

Table 2. Means of bond strength (MPa) and Standard Deviation of tested materials

Groups	n	Mean(MPa)	Std. Dev.
MTA Angelus	20	5,809a	0,712
BIOfactor MTA	20	5,575a	0,486
AH Plus	20	6,657a	0,465

Table 3. Failure types

Groups	Failure Types (%)		
	Adhesive	Cohesive	Mix
MTA Angelus	4(%20)	8(%40)	8(%40)
BIOfactor MTA	4(%20)	8(%40)	8(%40)
AH Plus	2(%10)	12(%60)	6(%30)

Results of Micro-CT Analysis

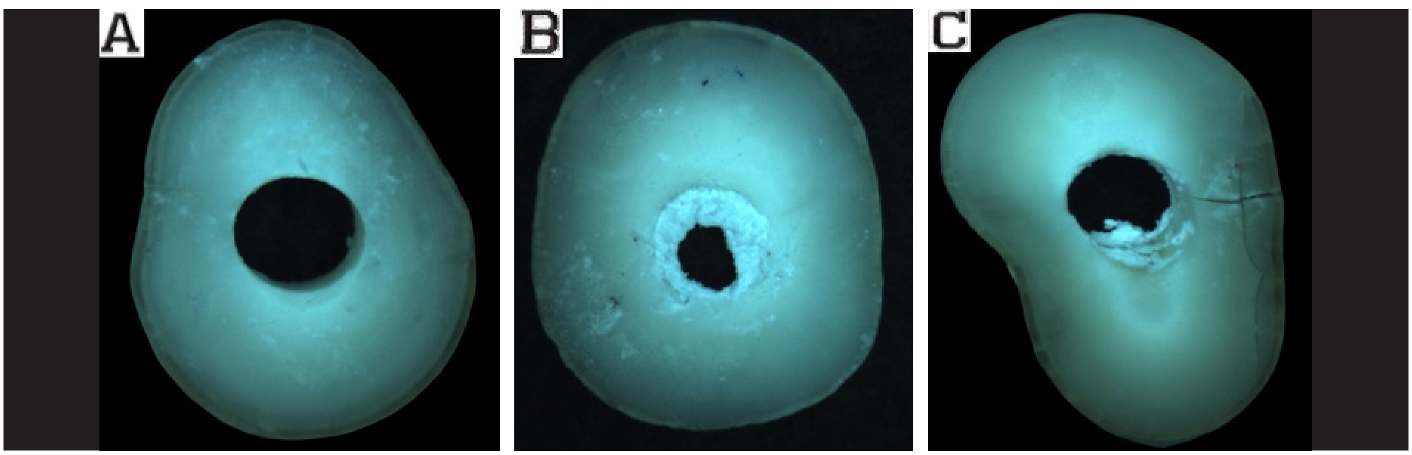

Figure. 2. Stereomicroscope images of the failure modes from each group: Adhesive failure(A), Cohesive failure (B), and Mix failure(C)

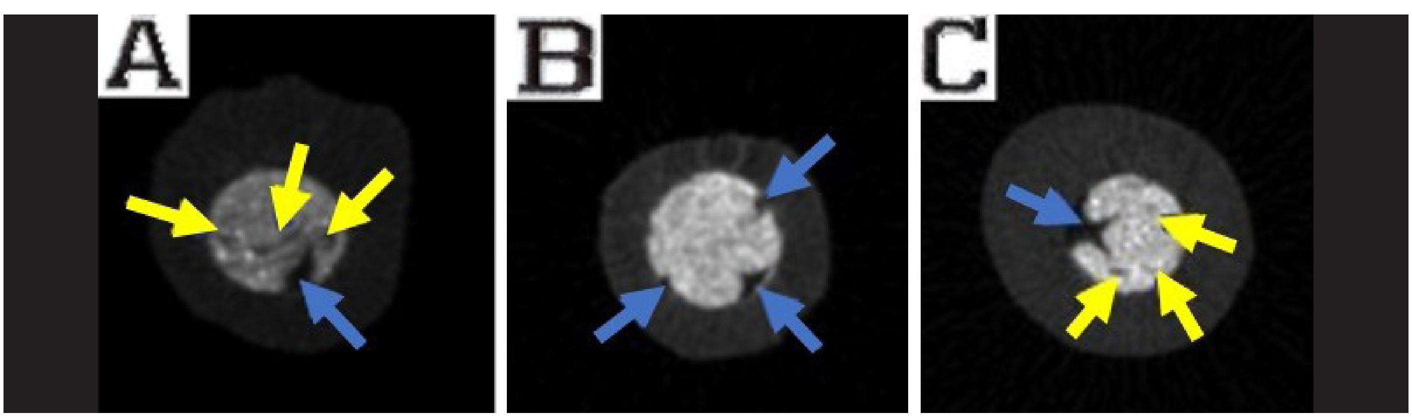

Figure. 3. Representative sections obtained in the N-recon program: Blue arrows show external voids which between the dentin walls and MTA and yellow arrows show porous voids inside the MTA.

Representative sections obtained from samples are shown in Figure 2 A-C. The medians and standard deviations as percentage values for each group are presented in Table 4. Where MTA Angelus and BIOfactor MTA were placed using the indirect ultrasonic activation technique, the external voids were found to be statistically significantly lower ($p < 0.05$). However, no significantly difference was found between them in terms of porous voids ($p > 0.05$). There was no statistically significant difference between the MTA Angelus and BIOfactor MTA groups placed with the hand condensation technique in terms of external voids or porous voids ($p > 0.05$).

Table 4. The external voids between the dentinal walls and MTA, the porosity inside the MTA percentage values (%)

	External voids between dentin walls and MTA (%)	Porous voids inside MTA (%)
Group	**Mean ± Std Dev.**	**Mean ± Std Dev.**
1 Angelus-Manuel	6,383±0,931[a]	0,672±0,194[a]
2 BIOfactor- Manuel	6,828±0,691[a]	0,685±0,107[a]
3 Angelus- Indirect	3,165±0,379[b]	0,687±0,168[a]
4 BIOfactor-Indirect	2,836±0,360[b]	0,793±0,101[a]

*Different letters in the same row mean the presence of statistically significant difference.

DISCUSSION

The study hypothesis was accepted because no significantly difference was found between the MTA Angelus and injectable BIOfactor MTA in terms of adaptation and structural porosity ratios of types of cement to dentin, and their bond strength to root dentin when used as an apical plug.

MTA is a successful apical plug with strong chemical and physical properties; it has become the most preferred material in the single-visit apexification technique for open apex teeth, thanks to its superior sealing, biocompatibility, and regenerative properties [14,15]. Giuliani et al. stated that apexification treatments with MTA were completed in a shorter time, the recovery time was shortened, and appointments were decreased [16]. Despite all the advantages of MTA, studies are continuing to strengthen its physical properties and improve the application technique. In this study, to evaluate the factors that will affect the success of apical plugs using MTA Angelus and BIOfactor MTA, the sealing ability and porosity when different placement techniques were used and bond strength to root dentin were investigated.

Adhesion of the endodontic repair material to the root dentin and sealing efficiency is directly proportional, and as they increase, the filling–dentin interface gets stronger, and the success of the treatment increases. In addition, the properties of the tooth, the application technique, and the material properties affect the quality of the dentin bond. Although there are many methods to measure the bond strength of endodontic materials to dentin, it has been reported that the push-out bond strength test is an effective, and practical method [17]. In this study, the dentin bond strengths of MTA materials were compared with the AH Plus-control group using the push-out test. Samples were prepared as in the study of Ersoy et al. [18]. In the literature, the bond strength values of MTA to root canal dentin have been reported as being between 1.66 and 9.46 MPa [19]. In this study, the bond strengths to root canal dentin were found to be 5.809 MPa for MTA Angelus and 5.575 MPa for BIOfactor MTA, both of which are within the above mentioned range; there is no statistical difference between them. According to the manufacturers, since the basic compositions of calcium-silicate-based materials are similar, their bond strengths are also similar. The bond strength of AH Plus was found to be the highest, at 6.657 MPa. The higher resistance of AH Plus to dislocation has been demonstrated previously [9], and this may be due to the formation during the mixing of a hard and strongly cross-linked polymer from a covalent bond between the diepoxide compounds and the polyamine paste [20].

There are not many studies in the literature comparing the dentin bond strength of BIOfactor MTA. In a study evaluating the bond strength using MTA Angelus, Biodentine, and BIOfactor MTA materials, root dentin slices were obtained from the middle third of the root, three different standard cavities were opened to each root slice, and the tested materials were applied. The bond strength of the three materials was similar, and cohesive-type failure was reported in most of the samples [21].

Another recent study evaluated the effect of the different adhesion methods for Biodentine and BIOfactor MTA using the dentin micro shear bond strength test. The bond strength value of Biodentine was found to be significantly higher than that of the MTA. BIOfactor MTA had a higher cohesive-type failure rate compared to Biodentine, regardless of the interface materials applied [22]. In this study, the fewest adhesive-type failures were observed in the MTA groups at the bonding interfaces examined with a stereomicroscope. This confirmed that, after a long period, the bond strength of the MTA material increased, and consequently it was more difficult to separate from the root dentin [23]. The prepared samples were kept in an environment moistened with PBS for 1 week, and it is known that calcium silicate–based materials interact with teeth by forming label-like structures in the presence of PBS [24,25]. The results obtained in our study are in alignment with the literature. In Angelus and BIOfactor MTA groups, 20% adhesive-type fractures, 40% cohesive-type fractures, and 40% mixed-type fractures were observed. It is possible to say that MTA Angelus and BIOfactor MTA materials, which do not have a statistically significant difference in bond strength values, are similar in terms of bonding quality to root dentin. In the AH Plus group, 10% adhesive-type failure was observed, the lowest adhesive-type failure rate.

The apical plug application part of this study was planned according to the study by Hachmeister et al. in which they emphasized the effect of MTA placement techniques [26]. In addition, preparation steps and MTA plug thickness were applied according to the in vitro model suggested by DeAngelis et al. [27]. The sealing efficiency of endodontic repair materials has been evaluated using different techniques: leakage tests, SEM analyses, and radiographic evaluations. These methods have some disadvantages, such as being insufficient to examine the filling quality in detail or having preparation steps that damage the samples [28]. For these reasons, a micro-CT advanced imaging technique, which provides three-dimensional imaging and enables precise measurements, such as surface area and void volume, was used for the microleakage evaluation [29,30].

Regarding the MTA placement technique, hand condensation, the traditional method, has been compared with the ultrasonic activation technique in many studies. Researchers have reported that indirect ultrasonic activation is a more suitable method for mimicking clinical situations than direct ultrasonic activation and hand condensation [5–7,31,32].

In this study, when the groups were compared in general in terms of placement techniques, the percentages of external voids of the Angelus and BIOfactor groups in which MTAs were placed by hand condensation were found to be statistically significantly higher than the Angelus and BIOfactor groups in which MTAs were placed by indirect ultrasonic activation. When evaluated in terms of porous spaces, there was no statistical difference between the groups according to the placement technique. When MTAs were placed with indirect ultrasonic activation, there may be fewer external voids observable because of the better flow on the root canal wall and better adhesion. Thus, the data we obtained in this study support the literature.

As a secondary result, when Angelus and BIOfactor MTA groups with the same placement technique were compared, no statistical difference was found between placement by manual densification or indirect ultrasonic activation. When MTA Angelus and BIOfactor MTA were compared, the lack of a significant difference in gap percentages, dentin wall compatibility, and homogeneity values can be attributed to similar homogeneity and the presence of particles of similar size and shape.

Yeung et al. applied MTA on acrylic blocks by manual densification and indirect ultrasonic activation for 1 second [31]. In the groups in which MTA was placed using indirect ultrasonic activation, less porosity was found even in curved canals. According to the results of the study by Kim et al. an MTA apical plug had significantly less resistance to bacterial leakage when hand condensation was performed [32]. In addition, Lawley et al. examined the MTA apical plugs placed using different techniques with the bacterial leakage test and reported that ultrasonics could be used to increase the efficiency of the MTA placement technique and the flow of MTA [7]. They observed that the MTAs placed with indirect ultrasonic activation had less porosity radiographically. This information aligns with the findings of our study in terms of placement technique. On the other hand, Aminoshariae et al. applied different thicknesses of MTA plugs, examined both with light microscopy and radiography, and reported that it showed better adaptation when applied with hand condensation [6]. Although there is no clear information about the duration of ultrasonic activation in this study, the direct application of ultrasonic energy to MTA may have led to uncontrolled condensation and more hollow fillings. In addition, it is known that both examination techniques used are less than adequate for examining the internal structure of a material.

El-Ma'aita et al. who used micro-CT after placing MTA with hand condensation and indirect ultrasonic activation, found less porosity in hand condensation. They also reported that the voids decreased when they prolonged the ultrasonic activation time [5]. However, these results were different from previous studies and our own. Although we produced 4 mm MTA apical plugs, El-Ma'aita et al. filled the entire 15 mm long canal space with MTA and delivered ultrasonic energy to each layer, which may have resulted in excessive energy transfer to the MTA, degradation of the material, and poorer adaptation. From the information provided, we think that indirect ultrasonic energy may have caused the distribution of heterogeneous particles of MTA, resulting in a more compact apical plug compared to the manual condensation technique.

Sisli and Özbaş evaluated the leakage of ProRoot and MTA Angelus apical plugs by manual condensation and indirect ultrasonic activation with micro-CT and found that the porosity values between dentin walls and apical plugs were significantly higher in MTA Angelus groups than in ProRoot MTA groups [13]. In the same study, it was found that ProRoot MTA provided higher adaptation than MTA Angelus when placed using hand condensation. However, when placed using indirect ultrasonic activation, they were found to be statistically similar in terms of the dentinal wall and the mean space between them. In our study, the mean gap between the dentin wall and MTA in the hand condensation group was 6.383% for MTA Angelus and 6.828% for BIOfactor MTA, also statistically similar. Likewise, while the mean space between the dentin wall and MTA was 3.165% in the group where MTA Angelus was placed with indirect ultrasonic activation and 2,836% in the group in which BIOfactor MTA was used, also statistically similar.

There is no study in the literature evaluating the microleakage of BIOfactor MTA. This study is a pioneering assessment of this topic. Therefore, further studies are needed to compare the results.

Limitations

One of the limitations of this study is that the total number of test samples for Micro- CT analysis (n = 72) was a small sample size. Another limitation is that the consistency of injectable BIOfactor MTA cannot be standardised.

CONCLUSIONS

Within the limitations of this in vitro study, AH Plus, MTA Angelus, and BIOfactor MTA materials showed similar results in terms of their dentin bond strength and fracture types, and adhesive-type fracture was minimal in all groups, with the lowest rate found in the AH Plus samples. BIOfactor MTA showed similar results to MTA Angelus in terms of adaptation to dentinal walls, regardless of placement technique. It is thought that this result might be related to similar particle sizes and homogeneity. When MTA Angelus and BIOfactor MTA were placed using indirect ultrasonic activation, the porosity rates were found to be lower than when using hand condensation. Further studies are needed to evaluate the effects of using micro-CT on clinical outcomes to determine whether the sealing efficiency and porosity of the MTA apical plug applied for apexification inpatient treatments can be increased by indirect ultrasonic activation. Although our study with BIOfactor MTA, a newly developed material, has given successful results, further studies on other properties of the material such as biochemical and physical properties are required.

Conflict of interest: The authors deny any conflicts of interest related to this study.

Informed Consent: This study was an in-vitro study, so an informed consent form not be added.

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Ethical Approval: Ethical approval was obtained from Selçuk University Clinical Research Ethics Committee (2017-09/14).

Author Contributions: Conception: MS,B;T,TK - Design: MS,B;T,TK - Supervision: MS,B; T,TK -Materials: T,TK - Data Collection and/or Processing: T,TK - Analysis and/ or Interpretation: MS,B;T,TK - Literature: T,TK - Review: MS,B;T,TK - Writing: T,TK - Critical Review: MS,B;T,TK .

REFERENCES

[1] Torabinejad M, Parirokh M, Dummer PMH (2018) Mineral trioxide aggregate and other bioactive endodontic cements: an updated overview–part II: other clinical applications and complications. Int Endod J.51(3):284–317. https://doi.org/10.1111/iej.12843

[2] Torabinejad M, Hong CU, McDonald F et al (1995) Physical and chemical properties of a new root-end filling material. J Endod. 21(7):349–353. https://doi.org/10.1016/S0099-2399(06)80967-2

[3] Lee SJ, Monsef M, Torabinejad M (1993) Sealing ability of a mineral trioxide aggregate for repair of lateral root perforations. J Endod. 19(11):541–544. https://doi.org/10.1016/S0099-2399(06)81282-3

[4] Küçükkaya Eren S, Parashos P (2019) Adaptation of mineral trioxide aggregate to dentine walls compared

with other root-end filling materials: A systematic review. Australian Endodontic Journal. 45(1):111–121. https://doi.org/10.1111/aej.12259

[5] El-Ma'aita AM, Qualtrough AJE, Watts DC (2012) A micro–computed tomography evaluation of Mineral Trioxide Aggregate root canal fillings. J Endod. 38(5):670–672. https://doi.org/10.1016/j.joen.2012.01.009

[6] Aminoshariae A, Hartwell GR, Moon PC (2003) Placement of mineral trioxide aggregate using two different techniques. J Endod. 29(10):679–682. https://doi.org/10.1097/00004770-200310000-00017

[7] Lawley GR, Schindler WG, Walker III WA et al (2004) Evaluation of ultrasonically placed MTA and fracture resistance with intracanal composite resin in a model of apexification. J Endod. 30(3):167–172. https://doi.org/10.1097/00004770-200403000-00010

[8] Kim H, Kim Y, Nam S et al (2016) Evaluation of sealing effect and working time of root canal filling MTA materials. JOURNAL OF THE KOREAN ACADEMY OF PEDTATRIC DENTISTRY. 43(2):129–136. https://doi.org/10.5933/JKAPD.2016.43.2.129

[9] Silva EJNL, Carvalho NK, Prado MC et al (2016) Push-out bond strength of injectable pozzolan-based root canal sealer. J Endod. 42(11):1656–1659. https://doi.org/10.1016/j.joen.2016.08.009

[10] [Atas O, Aras A (2021) Investigation of the change in color caused by the contact of calcium silicate-based materials with endodontic irrigation solutions. Journal of Dental Research and Review. 8(2):82. https://doi.org/10.4103/jdrr.jdrr_134_20

[11] FatihÖznurhan BusraKeskus M (2020) Evaluation of Long-Term Results of Two Different Calcium Silicate Based Materials in Primary Molar Teeth Vital Pulpotomies: An Invivo Study. Cumhuriyet Dental Journal. 23(1):45–51. https://doi.org/10.7126/cumudj.648723

[12] Silujjai J, Linsuwanont P (2017) Treatment outcomes of apexification or revascularization in nonvital immature permanent teeth: a retrospective study. J Endod. 43(2):238–245. https://doi.org/10.1016/j.joen.2016.10.030

[13] Sisli SN, Ozbas H (2017) Comparative micro–computed tomographic evaluation of the sealing quality of ProRoot MTA and MTA Angelus apical plugs placed with various techniques. J Endod. 43(1):147–151. https://doi.org/10.1016/j.joen.2016.09.017

[14] BAKIR EP, BAKIR Ş, Samican Ü (2021) Comparison of antibacterial effects of pulp capping materials. Selcuk Dental Journal. 8(2):553–560. https://doi.org/10.15311/selcukdentj.896007

[15] Kumar GA, Anusha T (2010) Single visit apexification with mineral trioxide aggregate. Annals & Essences of Dentistry. 2(3):106–109. https://doi.org/10.5368/aedj.2010.2.3.106-109

[16] Giuliani V, Baccetti T, Pace R et al. (2002) The use of MTA in teeth with necrotic pulps and open apices. Dental Traumatology. 18(4):217–221. https://doi.org/10.1034/j.1600-9657.2002.02107.x

[17] Van Meerbeek B, Peumans M, Poitevin A et al (2010) Relationship between bond-strength tests and clinical outcomes. Dental materials. 26(2):e100–121. https://doi.org/10.1016/j.dental.2009.11.148

[18] ERSOY İ, OK E, ERTAŞ H et al (2016) Comparison of Push-Out Bond Strength of Three Calcium Silicate Cements to Dentin. Turkiye Klinikleri Journal of Dental Sciences. 22(1). https://doi.org/10.1007/s00784-013-1082-4

[19] Guneser MB, Akbulut MB, Eldeniz AU (2013) Effect of various endodontic irrigants on the push-out bond strength of biodentine and conventional root perforation repair materials. J Endod. 39(3):380–384. https://doi.org/10.1016/j.joen.2012.11.033

[20] Fisher MA, Berzins DW, Bahcall JK (2007) An in vitro comparison of bond strength of various obturation materials to root canal dentin using a push-out test design. J Endod. 33(7):856–868. https://doi.org/10.1016/j.joen.2007.02.011

[21] Akbulut MB, Bozkurt DA, Terlemez A et al (2019) The push-out bond strength of BIOfactor mineral trioxide aggregate, a novel root repair material. Restor Dent Endod. 44(1). https://doi.org/10.5395/rde.2019.44.e5

[22] Gürcan AT, Şişmanoğlu S, Sengez G (2022) Effect of Different Adhesive Strategies on the Microshear Bond Strength of Calcium-Silicate-Based Materials. J Adv Oral Res. 13(2):191–199. https://doi.org/10.1177/23202068221118

[23] Darvell BW, Wu RCT (2011) “MTA”—an hydraulic silicate cement: review update and setting reaction. Dental Materials. 27(5):407–422. https://doi.org/10.1016/j.dental.2011.02.001

[24] Reyes-Carmona JF, Felippe MS, Felippe WT (2010) The biomineralization ability of mineral trioxide aggregate and Portland cement on dentin enhances the push-out strength. J Endod. 36(2):286–91. https://doi.org/10.1016/j.joen.2009.10.009

[25] Han L, Okiji T (2011) Uptake of calcium and silicon released from calcium silicate–based endodontic materials into root canal dentine. Int Endod J. 44(12):1081–1087. https://doi.org/10.1111/j.1365-2591.2011.01924.x

[26] Hachmeister DR, Schindler WG, Walker III WA et al (2002) The sealing ability and retention characteristics of mineral trioxide aggregate in a model of apexification. J Endod. 28(5):386–390. https://doi.org/10.1097/00004770-200205000-00010

[27] DeAngelis L, Chockalingam R, Hamidi-Ravari A et al (2013) In vitro assessment of mineral trioxide aggregate setting in the presence of interstitial fluid alone. J Endod. 39(3):402–405. https://doi.org/10.1016/j.joen.2012.11.010

[28] Naseri M, Kangarlou A, Khavid A et al (2013) Evaluation of the quality of four root canal obturation techniques using micro-computed tomography. Iran Endod J. 8(3):89. https://pubmed.ncbi.nlm.nih.gov/23922567/

[29] Rhodes JS, Ford TRP, Lynch JA, et al (1999) Micro-computed tomography: a new tool for experimental endodontology. Int Endod J. 32(3):165–170. https://doi.org/10.1046/j.1365-2591.1999.00204.x

[30] Rattanasak U, Kendall K (2005) Pore structure of cement/pozzolan composites by X-ray microtomography. Cem Concr Res. 35(4):637–640. https://doi.org/10.1016/j.cemconres.2004.04.022

[31] Yeung P, Liewehr FR, Moon PC (2006) A quantitative comparison of the fill density of MTA produced by two placement techniques. J Endod. 32(5):456–459. https://doi.org/10.1016/j.joen.2005.08.008

[32] Kim US, Shin SJ, Chang SW, Yoo HM, Oh TS, Park DS (2009) In vitro evaluation of bacterial leakage resistance of an ultrasonically placed mineral trioxide aggregate orthograde apical plug in teeth with wide open apexes: a preliminary study. Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology. 107(4):e52–56. https://doi.org/10.1016/j.tripleo.2008.12.049

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