



## Effect of Different Irrigation Activation and Condensation Techniques on the Marginal Adaptation of White MTA

### Farklı İrrigasyon Aktivasyon ve Kondenzasyon Tekniklerinin Beyaz MTA'nın Marjinal Adaptasyonuna Etkisi

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#### Abstract

**Objective:** To evaluate the effect of different irrigation activation and condensation techniques on the marginal adaptation ability of white ProRoot mineral trioxide aggregate (MTA).

**Materials and Methods:** Eighty single-rooted human teeth were prepared to a ProTaper Universal F4 file. Initially, the roots were randomly divided into four groups as follows: conventional syringe irrigation in group 1, sonic activation (EDDY) in group 2, passive ultrasonic irrigation in group 3, and Er:YAG laser in group 4. Then, ProRoot MTA was set with hand condensation or ultrasonic condensation techniques, and the adaptation ability of MTA was investigated using SEM.

**Results:** EDDY activation had the lowest gap scores ( $p<0.001$ ). No statistical differences were observed between the regions ( $p>0.05$ ), and condensation techniques ( $p>0.05$ ).

**Conclusion:** The marginal adaptation of ProRoot MTA to root dentine increased with EDDY activation, and the marginal adaptation ability of the material was not affected by the condensation technique.

**Keywords:** Adaptation, EDDY, mineral trioxide aggregate, PIPS, PUI

#### Öz

**Amaç:** Farklı irrigasyon aktivasyon ve kondenzasyon tekniklerinin ProRoot mineral trioksit agregat'ın (MTA) marjinal adaptasyon yeteneği üzerindeki etkisini değerlendirmektir.

**Gereç ve Yöntemler:** Seksen tek köklü insan dişi ProTaper Universal F4 eğesine kadar genişletildi. Dişler grup 1'de geleneksel şırınga ile irrigasyon, grup 2'de sonik aktivasyon (EDDY), grup 3'te pasif ultrasonik irrigasyon ve grup 4'te Er:YAG lazer kullanılmak üzere rastgele dört gruba ayrıldı. Sonrasında ProRoot MTA elle kondenzasyon veya ultrasonik kondenzasyon teknikleri ile kondenze edildi ve SEM kullanılarak MTA'nın adaptasyon yeteneği değerlendirildi.

**Bulgular:** EDDY aktivasyonu ile en düşük boşluk skorları elde edildi ( $p<0,001$ ). Bölgeler ve kondenzasyon teknikleri arasında istatistiksel bir farklılık gözlenmedi ( $p>0,05$ ), ( $p>0,05$ ).

**Sonuç:** ProRoot MTA'nın kök dentinine marjinal adaptasyonu, EDDY aktivasyonu ile arttı ve materyalin marjinal adaptasyon özelliği kondenzasyon tekniğinden etkilenmedi.

**Anahtar Kelimeler:** Adaptasyon, EDDY, mineral trioksit agregat, PIPS, PUI

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## Introduction

Tricalcium silicate cement is aimed to hermetically seal the dentin against leakage and may induce hard tissue formation if in contact with periapical tissues (1). In the past, mineral trioxide aggregate (MTA) was the first used tricalcium silicate cement in many areas: such as retrograde filling, apexification, vital pulp therapy, and perforation repair. MTA still contributes desired results, similar to the recently developed bioceramic-based cements (2). Investigating its marginal adaptation on dentine walls can help to understand sealing ability of MTA (1).

The smear layer hampers penetration of disinfecting agents and blocks sealer penetration in root canal treatment (3). Many devices and technologies, including sonics, ultrasonics, and lasers, have been used for irrigation activation to enhance smear layer removal. Sonic activation is similar to ultrasonic activation, but sonic devices generally use a flexible tip and activate at lower frequencies under 20 kHz.

With the recently developed sonic activation Endo Irrigation Tip (EDDYM; VDW GmbH, Munich, Germany), which has a non-cutting flexible tip size of 25/0.04, a new standard for safety and efficiency in activation was gained. Three-dimensional movement of the tip supports acoustic streaming in the root canal, contributing to higher cleaning efficiency (4). The frequency parameter of this tip is between 5,000–6,000 Hz (4), and it works with an air-driven handpiece (TA-200-S4H, Micron, Tokyo, Japan). With ultrasonic devices, acoustic microstreaming is produced during their application. As an activation technique, ultrasonic tips can increase the performance of irrigation solutions (5). Small non-cavitating bubbles are created by ultrasonic systems, by which acoustic microstreaming and shear stresses are produced on the root canal surface (4).

In previous studies, Er:YAG laser was indicated to be a valuable tool for removing the smear layer (6). As a technique to be used with Er:YAG laser, photon-induced photoacoustic streaming (PIPS™), which has a stripped tip to be placed into the canal orifice, has been shown to be effective as an irrigation activation technique in debris and smear layer removal. Working principle of the photoacoustic shock waves is explained by inducing 3-dimensional stream of the irrigation solution throughout the root canals (7).

Condensation procedures includes a technique, a well-known simple hand condensation, in which an endodontic condenser, a plugger is used. Other procedure is a modified technique where hand condensation and ultrasonic vibration are combined.

The effects of smear layer removal and adaptation of different root canal materials on dentine walls have been evaluated in many previous studies (2,4). Nonetheless, it is still necessary to evaluate the adaptation of MTA-based cements after using EDDY, a newly developed effective tool. It is also valuable to compare the effect of EDDY with passive ultrasonic irrigation (PUI) and Er:YAG laser (PIPS) activation on the adaptation. Therefore, the aim of this study

was to investigate the marginal adaptation of ProRoot MTA (Dentsply Maillefer, Ballaigues, Switzerland) by using two different condensation technique after performing EDDY, PUI or Er:YAG irrigation activation.

## Materials and Methods

Ethics approval (approval number: 2021.07.01, date: 08.07.2021) was granted for this study by the Kırıkkale University Non-Interventional Research Ethics Committee. According to a power analysis (G\*Power Version 3.0.10, Kiel University, Germany) (F tests, effect size  $f=0.40$ ,  $\alpha$  error probability  $=0.05$ ,  $1-\beta$  error probability  $=0.80$ ), the minimum required sample size was 80 specimens. A total of 80 single-rooted permanent human teeth were selected. More than a single root canal, open apex, resorption, fracture, or dilacerations were discarded. The digital images (Gendex Dental Systems, Hatfield, PA, USA) were taken from the teeth using buccal and proximal aspects to exclude a tooth with a complex root canal anatomy. The teeth not shorter than 14 mm root length and less than 10 degrees of curvature were chosen after obtaining periapical radiographs and were measured using ImageJ software (ImageJ v1.47, National Institutes of Health, USA). The remnants on root surface were removed and the teeth were stored in distilled water during the sample collection. After the preparation of access cavities, the working length was determined by inserting #15 K-file, and the root canals were prepared with ProTaper Universal (Dentsply, Maillefer, Switzerland) up to #F4. The root canals were rinsed with 2 mL 5% NaOCl for 1 min between each instrument. Finally, the root canals were irrigated with distilled water and dried with sterile paper points. Then, the samples were randomly divided into four groups ( $n=20$ ).

In group 1 [conventional syringe irrigation (CSI)], the root canals were rinsed with 5 mL 5% NaOCl for 60 s. The irrigation solutions were applied to the root canal by the aid of a 30 G endodontic irrigation needle with up and down movement. No further activation was performed. This procedure was repeated using 5 mL 17% EDTA for 60 s. A 2 mL distilled water was used between each solutions. In group 2, with sonic activation tip (EDDY), 5% NaOCl was activated for 10 s at the same time with irrigation. Tip was used with a frequency of 6000 Hz at 1-mm shorter than the working length and in-and-out motion (TA-200-S4H, Micron, Tokyo, Japan). After the activation is completed a 10 second resting period was waited to repeat the procedure. This process was repeated in three-time intervals (10 s for the irrigation and activation and 10 s for the resting period) and completed in 60 s per irrigant. Irrigation and activation procedures were followed using 5 mL 17% EDTA. In group 3 (PUI) the irrigation solutions were applied with an irrigation needle, and activated using a stainless steel ultrasonic tip (NSK, Nakanishi Inc., Tokyo, Japan) with a MiniEndo II Ultrasonic Unit (SybronEndo, Orange, CA) at ½ power setting for 60 s similar to group 1. In group 4, Er:YAG laser activation, the irrigation, and

activation procedures were performed as described in the first group. The irrigation activation was applied with an Er:YAG laser (LightWalker, Fotona, Ljubljana-Slovenia) by inserting a 300 µm fiber tip (PIPS) into the access cavity. The laser parameters were set to 0.3 W, 15 Hz, and 20 mJ in quantum square pulse mode.

Finally, after rinsing the root canals with 5 mL distilled water, apical portion of the root with 3 mm thickness was removed, and two 1 mm thickness dentine discs were obtained using a precision cutting machine (Metkon 151, Bursa, Turkey) under constant water flow at 1<sup>st</sup> mm (apical) and 7<sup>th</sup> mm (coronal) of the resected roots. Afterward, each group was divided into two subgroups of 10 samples according to MTA condensation techniques (hand condensation or ultrasonic condensation).

According to the manufacturer's recommendations, ProRoot MTA was applied to dentine discs using a plugger (Dentsply, Ballaigues, Switzerland) condensation with or without ultrasonic vibration (Woodpecker, Guangxi, China). Ultrasonic vibration speed was set to low potency and applied for 5 s for each sample in contact with the plugger tip. When obturation was completed, the remaining material on the dentine surface was cleaned with a cotton pellet. Then, an amount of sponge was moistened using saline solution and placed on the material. All samples were stored at 100% humidity at 37 °C for 24 h to set. Afterwards, eight measuring points were signed, as evenly as possible, around the material under an operation microscope (Zeiss S100/OPMI Pico, Germany) at X10 magnification. The samples were coated with gold-palladium alloy using a coating machine (Balzers-SCd 050, Germany) and evaluated under a scanning electron microscope (SEM) (Jeol JSM-5600, Tokyo, Japan). The gaps between the material and dentin wall were measured linearly in micrometers on clockwise cross-sections (Figure 1a), and the failed samples (Figure 1c) were prepared again.

### Statistical Analysis

The SPSS 22.0 software (IBM, Armonk, NY) was used for statistical analysis, and p-values were established at 0.05. Due to a lack of normal distributions, log 10 transformations were performed to homogenize the variances and decrease the number of outliers. Thus, two-way ANOVA, Tukey tests, and Independent-Samples t-tests were used for statistical analysis.

### Results

Gaps between the MTA and dentin were observable in all groups at different magnifications (Figure 2, 3). The mean and standard deviation of the values for the gap measurements obtained on the SEM images are shown in Table 1. There was a significant difference in the adaptation of MTA between the groups ( $p < 0.001$ ). The lowest gap values were observed in group 2 with the sonic activation. There was no significant difference between the coronal

and apical thirds in MTA adaptation ability ( $p = 0.096$ ). Moreover, no significant difference was found among the MTA condensation methods ( $p = 0.118$ ).

### Discussion

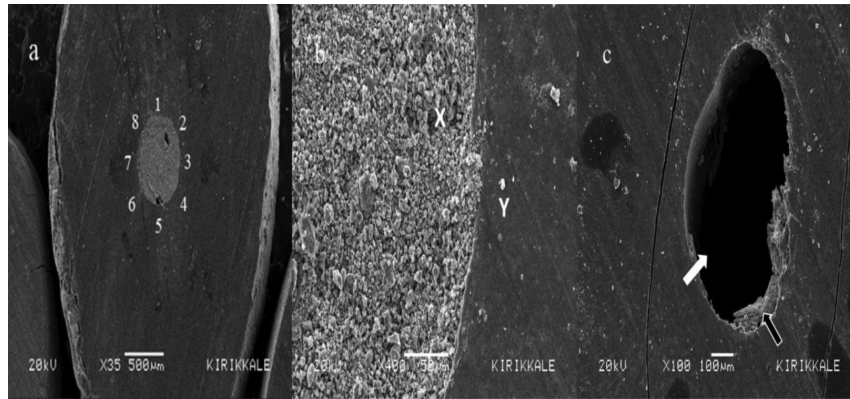
Adaptation ability is an expected feature of MTA-based repair materials and root canal sealers. Most of the samples in this study had a complete adaptation between the material and the dentine wall interfaces. On the other hand, if data could not be obtained from the sample due to adaptation failure, the sample was re-prepared and evaluated.

When comparing CSI with EDDY, sonic activation had significant differences regarding dentine and smear removal from curved canals (8). On the other hand the efficacy of sonic activation in terms of the adaptation of MTA and bioceramic-based cements has not been examined in previous studies. In this study, MTA adaptation after sonic activation had the lowest gap measurement and the highest marginal adaptation. As shown in an earlier study, number of the viable microorganisms decreased significantly with EDDY tips compared to passive ultrasonic irrigation (Irrisafe, Acteon, France) and manual irrigation (9). EDDY was more effective than XP-endo Finisher (FKG-Dentaire, La-Chaux-de-Fonds, Switzerland) in removing calcium hydroxide from artificial grooves, having a similar effect to PUI (10). Sonic activation with EDDY also enhances removal of residual filling materials during retreatment, as reported in a previous study with micro-CT (11).

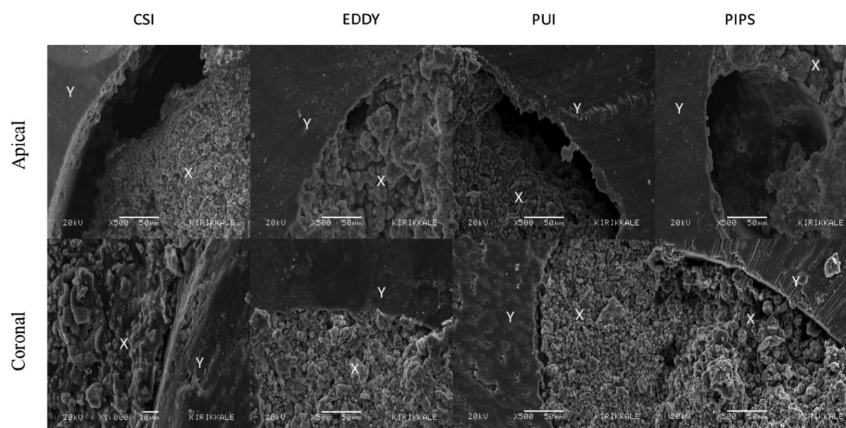
It was concluded in several studies that ultrasonics failed to enhance the smear layer removal efficiency of EDTA or a combination of NaOCl and EDTA (12,13). In this study, the PUI procedure had a lower performance than EDDY. Its performance was similar to that of PIPS. It was also reported that the sonic activation was significantly more efficient than PUI and laser-activated irrigation in smear layer removal at different levels of the root canal (14). However, another study showed that PUI and EDDY had similar performances in smear layer removal (4). Different frequencies for sonic and ultrasonic systems, different lasers at various wavelengths, and the study methods may affect the results.

When the crown is maintained as a reservoir for irrigant, the constant movement of the solution into root canals is possible without depletion of the irrigant (15). Therefore, the coronal portion of the teeth was not removed, and access cavities were used in this study. PIPS is activated in the pulp chamber, and EDDY is activated in the root canal. This difference between the application techniques resulted in a more remarkable adaptation ability in the EDDY group because of closer performance to the apical region and more mechanical agitation to the root dentine surface.

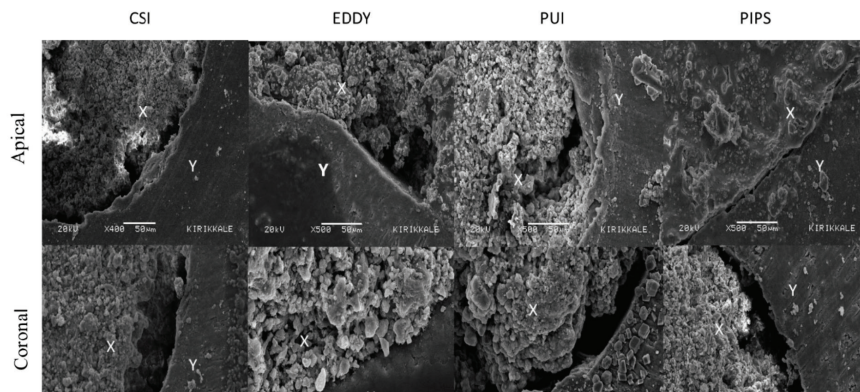
In the present study, there was no statistically significant difference in the adaptation ability of MTA after CSI, PUI, and PIPS activation there is no other study comparing the adaptation of MTA after using irrigation activation systems



**Figure 1.** a. The numbers show the sites selected for evaluation in each sample at x500 magnification. b. Showing a tight adaptation between MTA (X) and dentine wall (Y). c. Adaptation failure. Black arrow shows remaining material and white arrow shows root canal space  
MTA: Mineral trioxide aggregate



**Figure 2.** SEM micrograph of hand condensation groups. Gaps are showing between MTA (X) and root dentine (Y)  
SEM: Scanning electron microscope, MTA: Mineral trioxide aggregate, CSI: Conventional syringe irrigation, EDDY: Passive sonic activation, PUI: Passive ultrasonic irrigation, PIPS: Photoacoustic activation



**Figure 3.** SEM micrograph of ultrasonic condensation groups. Gaps are shown between MTA (X) and root dentine (Y)  
SEM: Scanning electron microscope, MTA: Mineral trioxide aggregate

**Table 1. The intergroup comparison between the irrigation methods and in intra-group comparisons between condensation techniques and regions. The data were shown as log 10 transformation**

|                   |                        |                        |                        |                   | Region                 |                        |
|-------------------|------------------------|------------------------|------------------------|-------------------|------------------------|------------------------|
|                   |                        |                        |                        |                   | Coronal                | Apical                 |
| Irrigation Method | Mean ± SD (µm)         | Condensation Technique | Mean ± SD (µm)         | Irrigation Method | Mean ± SD (µm)         | Mean ± SD (µm)         |
| CSI               | 1.27±0.54 <sup>a</sup> | HC                     | 1.05±0.62 <sup>a</sup> | CSI               | 1.00±0.44 <sup>A</sup> | 1.15±0.80 <sup>A</sup> |
|                   |                        |                        |                        | EDDY              | 0.56±0.60 <sup>A</sup> | 0.38±0.53 <sup>A</sup> |
| EDDY              | 0.62±0.52 <sup>b</sup> |                        |                        | PUI               | 1.43±0.30 <sup>A</sup> | 1.45±0.36 <sup>A</sup> |
|                   |                        |                        |                        | PIPS              | 1.02±0.62 <sup>A</sup> | 1.44±0.23 <sup>A</sup> |
| PUI               | 1.40±0.45 <sup>a</sup> | UC                     | 1.20±0.55 <sup>a</sup> | CSI               | 1.36±0.23 <sup>A</sup> | 1.56±0.39 <sup>A</sup> |
| PIPS              | 1.23±0.56 <sup>a</sup> |                        |                        | EDDY              | 0.65±0.45 <sup>A</sup> | 0.87±0.45 <sup>A</sup> |
|                   |                        |                        |                        | PUI               | 1.19±0.64 <sup>A</sup> | 1.52±0.41 <sup>A</sup> |
|                   |                        |                        |                        | PIPS              | 1.25±0.18 <sup>A</sup> | 1.20±0.88 <sup>A</sup> |
| p-value           | <0.001                 |                        | 0.118 <sup>#</sup>     |                   | 0.096 <sup>*</sup>     |                        |

CSI: Conventional syringe irrigation, EDDY: Passive sonic activation, PUI: Passive ultrasonic irrigation, PIPS: Photoacoustic activation, HC: Hand condensation, UC: Ultrasonic condensation.n

The same superscript lowercase letters in each column is not statistically significant (p>0.05). The same superscript uppercase letters in each row is not statistically significant (p>0.05), <sup>#</sup>HC-UC comparison <sup>\*</sup>Coronal-apical comparison

in the literature. On the other hand, it was reported in a study that MI, PUI, and PIPS had the same performance regarding apical debris extrusion (16).

In this study, sonic activation EDDY was the most effective method increasing MTA adaptation on the root dentine surface. Challenges in MTA application may be considered one of its drawbacks; different carriers including pluggers have been used for placement of MTA.

In recent studies, the ultrasonic vibration technique has been used during condensation to increase adaptation ability (17,18). It has been reported that the adaptation ability of MTA condensed with this technique increased in teeth with open apex (18). Contrarily, it was also shown that when MTA was condensed with ultrasonic tips, its sealing ability did not differ significantly compared to that of MTA condensed with paper points or pluggers (19).

Yeung et al. (20) showed that indirect ultrasonic vibration, after hand condensation, resulted in significantly denser MTA filling than the MTA filling applied by hand condensation alone. It was also concluded that ultrasonic vibration might be more beneficial at MTA placement for open apices than hand condensation and results in better MTA condensation (21). Sisli and Ozbas (22) reported no significant differences when comparing hand condensation and ultrasonic activation on MTA placement. However, another study (23) assessed MTA adaptability to the walls of polyethylene tubes using different application methods was reported that MTA placement by hand condensation led to better adaptation with fewer gaps than direct ultrasonic technique. Similarly, results of the present study indicated

that MTA condensation was not significantly different in these two techniques.

## Conclusions

MTA adaptation to the root dentine after sonic activation was more effective than MTA adaptation after the manual irrigation and ultrasonic activation techniques. The adaptation ability was also similar in the apical and coronal regions. Moreover, the use of ultrasonic vibration in MTA placement did not affect the adaptation of the material. Further studies are required to elucidate the correlation of different irrigation activation techniques and the adaptation of the MTA or bioceramic-based materials.

## Ethics

**Ethics Committee Approval:** Ethics approval (approval number: 2021.07.01, date: 08.07.2021) was granted for this study by the Kırıkkale University Non-Interventional Research Ethics Committee.

**Informed Consent:** Informed consent is not required.

**Peer-review:** Externally and internally peer-reviewed.

## Authorship Contributions

Concept: A.T., A.E., Design: A.T., A.E., Data Collection or Processing: A.T., Y.Ö., G.A.D., Analysis or Interpretation: A.T., Literature Search: A.T., Y.Ö., G.A.D., Writing: A.T., Y.Ö., A.E.

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