RESEARCH ARTICLE

CYPRUS JOURNAL OF MEDICAL SCIENCES

DOI: 10.4274/cjms.2022.2021-21

Cyprus J Med Sci 2023;8(4):292-298

Assessment of the Push-Out Bond Strength of Three Different Root-End Filling Materials in Retrograde Cavities Using Three Different Retro Preparation Techniques

Fatma Canbolat Eroğlu[1], F. Semra Sevimay[1], Berkan Çelikten[1], İsmail Özkoçak[4]

[1]Department of Endodontics, Ankara University Faculty of Dentistry, Ankara, Türkiye

[2]Department of Endodontics, Bolu Abant İzzet Baysal University Faculty of Dentistry, Bolu, Türkiye

Abstract

BACKGROUND/AIMS: The aim of this study was to evaluate the push-out bond strength of root-end cavities filled with different retrograde filling materials.

MATERIALS AND METHODS: Straight and single root canals of 180 maxillary incisor teeth were prepared, obturated, and randomly divided into nine groups (n=20 per group). In each group, one of the root-end cavity preparation techniques (drill, erbium:yttrium, aluminum-garnet laser, or ultrasonic retrotip) was applied and matched with a retrograde filling [ProRoot mineral trioxide aggregate (MTA), Tech Biosealer Root End, or Biodentine]. Three slices were sectioned from the root apex, and the middle ones were selected. They were placed in a universal testing machine, applying push-out force until bond failure occurred. The push-out bond strength values at bond failure were analyzed using Kruskal-Wallis H test and post-hoc multiple comparison test ($p<0.05$).

RESULTS: The bond strengths between the root-end cavities prepared with a bur, laser, and ultrasonic retrotip and the filling materials (MTA, Tech Biosealer Root End, and Biodentine) were determined to be statistically significantly different ($p<0.05$). The highest mean value occurred in the ultrasonic + Biodentine group, whereas the lowest mean value was seen in the bur + Tech Biosealer group. There were no statistical differences between the cavities prepared with laser and ultrasonic retrotip and filled with MTA and Biodentine ($p>0.05$). However, the mean bonding strength of Biodentine placed in cavities prepared with the drill was significantly higher than MTA and Tech Biosealer ($p<0.05$).

CONCLUSION: In laser-prepared cavities, Tech Biosealer showed lower bonding strength compared to the other materials. Similarly, in ultrasonic retrotip prepared cavities, Biodentine and MTA showed better bonding, while Tech Biosealer showed a weaker bonding.

Keywords: Retrograde cavity, laser, ultrasonic, Tech Biosealer Root End, Biodentine

INTRODUCTION

To have a successful outcome from endodontic treatment, the endodontist should seal the root canal to provide a fluid-tight seal in all three dimensions.[1] In some cases, pathological formations might occur at the periapical area, and applying a non-surgical process to remove them might not work effectively. For these cases, surgical action becomes necessary.[2] The rationale of endodontic surgery is the regeneration of the periapical tissues to a healthy state. It is a procedure which involves apical resection, root-end cavity preparation, and root-end filling. Surgical intervention is preferred when periapical pathology is resistant or one of the following is present: overfilled canals, a barrier in the canal, ridges, apical transportations, broken instruments, or perforations.[2,3]

To cite this article: Canbolat Eroğlu F, Sevimay FS, Çelikten B, Özkoçak İ. Assessment of the Push-Out Bond Strength of Three Different Root-End Filling Materials in Retrograde Cavities Using Three Different Retro Preparation Techniques. Cyprus J Med Sci 2023;8(4):292-298

ORCID IDs of the authors: F.C.E. 0000-0001-8293-4285; F.S.S. 0000-0002-9763-9358; B.Ç. 0000-0001-5645-5029; İ.Ö. 0000-0003-0820-0069.

Address for Correspondence: Fatma Canbolat Eroğlu
E-mail: canbolatfc@gmail.com
ORCID ID: orcid.org/0000-0001-8293-4285

Received: 25.01.2021
Accepted: 25.03.2022

To achieve successful results by endodontic surgery, one has to select a high-profile root-end filling material. In an ideal situation, it has to be biocompatible, to promote healing, to have good strength and excellent sealing ability, to be radiopaque, to not be affected by moisture, and to be easy to manipulate.[4] Numerous different materials have been used for root-end filling from the past to the present. The most common ones are amalgam, composite resins, glass ionomers, zinc oxide eugenol cement, mineral trioxide aggregate (MTA), and super ethoxy-benzoic acid.[5] Despite the distinct properties of these materials, none of them covered all of the above-mentioned properties of an ideal root-end filling material.[6] Nevertheless, calcium-silicate types of cement yielded improved clinical results compared to the other materials, owing to their hydraulic material properties.[7] Therefore, MTA, a calcium silicate cement, was proposed as an alternative material to overcome the shortcomings of the filling materials used in the past. While it had superior properties, the disadvantages of MTA were its longer setting time and being challenging to handle. For this reason, the search for a better material continued.[6,8] Subsequently, another calcium silicate-based material was introduced, named Biodentine (Septodont). It had beneficial properties such as good sealing ability, biocompatibility, easy manipulation, and a short setting time.[3] One of the latest materials put forward with calcium content was Tech Biosealer Root End. According to its manufacturers, it was biocompatible, and it had applications such as perforation repairing, root-end filling, and vital pulp therapy.[9,10]

The clinical success of endodontic surgery depends on another procedure, the method chosen for the root-end cavity preparation.[11] Traditionally, dentists use a bur to prepare root-end cavities. Still, this technique has several limitations such as causing microleakages, smear layer formation on the surface of the cavity, inadequate depth of the cavities, having limited access to the cavities causing an imperfect alignment to the long axis of the root and off-centered root-end preparation. These deficiencies increase the risk of lateral perforation.[2] To overcome these problems, ultrasonic retrotips were developed. Due to the shape of the ultrasonic tip, it has several advantages, such as producing a conservative, deep and centralized cavity with a refined shape. In addition, it helps to identify additional canals and unexpected isthmuses and it reduces the number of dentinal tubules exposed at the resected surfaces.[2,12] Despite its advantageous properties, its most typical drawback is the occurrence of dentin cracks observed after using ultrasonic retrotips, thuse affecting the apical seal.[13] Therefore, new methods are necessary. In recent years, in addition to ultrasonic tips, lasers have also been used as an alternative for retrograde cavity preparation. One example of hard-tissue lasers is erbium:yttrium, aluminum garnet (Er:YAG).[14] Practicing apicoectomy using Er:YAG has various benefits. It prevents dentine cracks because it does not contact the dentine and does not vibrate. In addition, it decreases the contamination probability at the operating field. It also reduces the possibility of traumatization in the surrounding tissues.[14] On the other hand, there is also a contrary opinion about the non-contact operation, seeing it as a disadvantage since there is no tactile feedback.[14,15]

Our study aimed to examine the push-out bond strength of three different root-end filling materials (ProRoot MTA, Tech Biosealer Root End, Biodentine) in cavities prepared using three different techniques (burs, ultrasonic retrotips, Er:YAG lasers). We expected to obtain statistically significant differences in bond strength values when different root-end filling materials and cavity preparation techniques were applied. The null hypothesis was to have no statistically significant difference in bond strength values when the inspected materials and techniques were combined.

MATERIALS AND METHODS

The study was performed at the Ankara University Faculty of Dentistry, and the Ethics Board approved the study protocol (approval number: 36290600/25). Informed consent was obtained.

In our study, 180 maxillary incisor extracted human teeth with a single and straight root canal and completely formed apices were used. Preoperative radiographs were taken to check the root canal anatomy. According to Schneider classification,[16] the radiographs were analyzed to select those teeth which had 5 degree or less root curvature, to verify that the canals were straight. Teeth with calcifications and broken tools were omitted from this study. The teeth were placed in 5% sodium hypochlorite (Werax, Spot Dental San., İzmir, Türkiye) for 60 minutes. The hard and soft tissue on the surface of the teeth was debrided with the help of a periodontal curette, and the teeth were stored in 0.9% physiological saline solution.

The preparation of access cavities was performed using a diamond-coated fissure bur. A number 10-K File (Dentsply, Maillefer, Ballaigues, Switzerland) was inserted 1 mm above the apical foramen to confirm canal patency. The working length was standardized at 22 mm for all teeth. Each diameter of the foramen apical was compatible with a number 15K-File (Dentsply, Maillefer, Ballaigues, Switzerland). For each tooth, root canals were prepared by ProTaper rotary files (Dentsply, Maillefer, Ballaigues, Switzerland) up to size F3. Between each file size, 2 mL of 5% sodium hypochlorite (Werax, Spot Dental San., İzmir, Türkiye) was applied. Then, the process was continued by flushing with 5 mL of EDTA (Werax, Spot Dental San., İzmir, Türkiye). Finally, the specimens were subjected to irrigation using 10 mL of distilled water, and dried using absorbent paper points. A master cone of size #30 was selected and confirmed via radiographs. The canals were filled with gutta-percha (Dentsply, Maillefer, Ballaigues, Switzerland) and AH Plus root canal sealer (Dentsply DeTrey, Konstanz, Germany) by the lateral compaction technique. Excess gutta-percha was removed with a hot instrument. To establish the quality of obturation, radiographs were taken along the directions of mesiodistal and buccolingual. Cavit (Cavit G ESPE, Seefeld, Germany) was used to seal the access cavities. The specimens were kept in an environment with a temperature of 37 °C and 100% humidity until the sealer was set.

Apical resection of all groups was performed at 90° to the long axis of the root and 3 mm from the apices by conventional fissure diamond bur. The selected teeth were randomly assigned to 9 groups (n=20 per group) which would be used to prepare root-end cavities and insert the retrograde filling materials (Table 1). In all groups, all retrograde cavities were prepared 3 mm deep using the selected technique of the group.

Groups 1 to 3 were prepared with a diamond-coated round bur (REF 806314, 010, Meisinger, Germany). Group 4, group 5, and group 6 were prepared with the Er:YAG laser system (Kavo Key 3+, KaVo, Biberach, Germany) with the following settings: the wavelength was 1.8 m, the energy was set at 450 mJ/pulse, the repetition rate was 4 Hz., and it was on contact mode with water cooling. Group 7, group 8, and group 9 were performed with a diamond-coated ultrasonic retrotip having an angle of 90° with a working length of 3 mm. (E30LD, NSK, Nakanishi Inc., Tokyo, Japan). The ultrasonic device was used at medium power.

Each specimen's cavity was measured to have 3 mm depth using a periodontal probe. After aligning the probe perpendicular to the long axis of the tooth, the width of the cavity was measured to be 1.5 mm.

All cavities were flushed with 5 mL physiological saline solution. The retrograde filling materials were inserted, and the samples were wrapped in wet gauze soaked with normal saline. Next, cement was prepared through mixing, following the instructions of the manufacturers. Retrograde fillings were carried out using ProRoot MTA (Dentsply Tulsa, Johnson City, TN, USA) for Groups 1, 4, and 7; Tech Biosealer Root End (Isasan, Rovello Porro, Co, Italy) for groups 2, 5, and 8; and Biodentine (Septodont, Saint-Maur-des-fosses, France) for groups 3, 6, and 9. The cavities were dried with a piece of cotton pellet. In each section, cement was inserted into the root canal cavity with an MTA gun (Dentsply Maillefer, Ballaigues, Switzerland). In this process, a hand plugger was used to compact the cement.

All of the samples were stored for a week in an environment of 37 °C and 100% humidity. All samples were embedded in self-curing acrylic blocks along their long axis so that the apex of the root-end could be seen from the acrylic.

Each embedded specimen's apical part was incised into 1 mm thick slices perpendicular to the long axis using a 0.3 mm thick diamond blade (Mikrotom, Stuers, Copenhagen, Denmark) and a low-speed saw (Metkon, Micracut precision cutter, Bursa, Türkiye). The incision was applied under constant water irrigation. Three slices of 1 mm thickness were dissected from each specimen, and only the middle-sliced disk was selected for testing.

The chosen dentine disks were placed in a universal testing machine (Lloyd LRX; Lloyd Instruments Ltd, West Sussex, UK). The samples were placed on an acrylic slab with a central hole of 1.5 mm diameter to allow the free motion of the plunger, which had a diameter of 0.6 mm. Since the disks had an ascending angle from apical to coronal, they were placed into the testing machine in order to receive force applied from the apical surface to eliminate any friction between the filling material and the dentin.

A compressive load was applied on the surface of materials at a 1 mm/min constant speed until failure occurred. At the time of dislodgement, computer software recorded the maximum load in Newtons (N). Then, the force values were converted to MPa to calculate the push-out bond strength (Figure 1).

Table 1. Experimental groups of the study

Group number	Root tip cavity method	Number of samples (n)	Retrograde filling material
1	Bur (conventional method)	20	ProRoot MTA
2		20	Tech Biosealer Root End
3		20	Biodentine
4	Laser system (Er:YAG)	20	ProRoot MTA
5		20	Tech Biosealer Root End
6		20	Biodentine
7	Ultrasonic retrotip	20	ProRoot MTA
8		20	Tech Biosealer Root End
9		20	Biodentine

Er:YAG: Erbium:yttrium, aluminum garnet, MTA: Mineral trioxide aggregate.

Statistical Analysis

Statistical analysis was performed using the non-parametric Kruskal-Wallis H test because the data was not normally disturbed according to Shapiro Wilk's test ($p<0.05$ for all variables). After the Kruskal-Wallis H test, the post-hoc Dunn's multiple comparison test was employed to determine which groups differed from each other (PASW Statistics 20; SPSS Inc., Chicago, IL, USA). The level of statistical significance was set at $p<0.05$.

RESULTS

In our study, the bond strength between the root-end cavities prepared with the bur, laser, and ultrasonic retrotip and the filling materials, MTA, Tech Biosealer Root End, and Biodentine were statistically significant ($p<0.05$), as shown in Table 2, 3.

The highest mean value was observed in the ultrasonic retrotip prepared and Biodentine filled group ($p>0.05$). In contrast, the lowest mean value was obtained in the bur prepared and Tech Biosealer filled group ($p<0.05$). Among the preparation techniques, there were no statistical differences between the cavities prepared with the laser and ultrasonic retrotip and filled with MTA and Biodentine ($p>0.05$). However, bur prepared cavities showed statistically significant and lower values than the other preparation techniques ($p<0.05$). In bur prepared cavities, the highest bond strength was seen in the Biodentine filled cavities ($p<0.05$). Tech Biosealer showed lower bonding strength than the other materials in the laser and ultrasonic retrotip prepared cavities ($p<0.05$). The statistical difference between MTA and Biodentine was not significant in those cavities prepared with the laser or the ultrasonic retrotip ($p>0.05$). Tables 2, 3 display the mean values, standard deviations, and the statistical analysis results of the Kruskal-Wallis H test along with post-hoc tests for all the groups.

DISCUSSION

The prognosis of apical surgery depends on how well the canal is obturated and sealed after performing cavity preparation. Therefore,

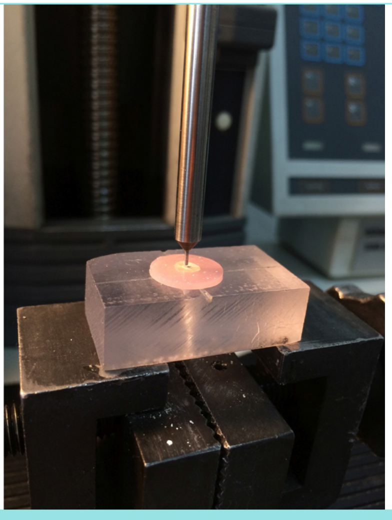

Figure 1. Universal test machine.

it is essential to prepare the cavity optimally to implement root-end filling adequately after apicoectomy.[13,17]

The selection of tooth specimens is essential for the study. Wu et al.[18] reported that they chose the same teeth groups with similar teeth length, similar root canal diameter, and similar root canal anatomies in order to eliminate variations. In addition, caries can degrade the mineral and organic composition of the samples.[19] Therefore, in this study, in order to standardize root canals and eliminate variations, we selected newly extracted, single, and straight rooted human maxillary incisors which had no caries or restorations.

One component of endodontic surgery is root-end resection. It promotes the elimination of debridement, pathological periradicular tissue, and anatomical variations. Applying 3 mm resection on the root apex will eliminate apical ramifications, lateral canals, resorptions, perforation defects, canal obstructions, and separated endodontic instruments.[13,17]

The ideal depth of the root-end cavity should be a 3 mm class I cavity with parallel dentin walls. If the cavity has less depth, apical ramifications and lateral canals cannot be removed, leading to unsuccessful treatment.[11] Hence, in this study, we performed the resection 3 mm above the root apex and prepared class I cavities with 3 mm of depth in order to deal with the difficulties mentioned above.

It is common to prepare root-end cavities with burs in a micro handpiece. However, this process results in various difficulties. Since the bur does not have an angle, it becomes difficult to prepare the cavity walls parallel to each other, it is not always possible to access to the root-end, and there is a heightened risk of lingual perforation of the root.[2] With the development of ultrasonic instruments, many of these problems have been solved. Ultrasonic retrotips are manufactured with various shapes and angles, so improving surgical treatment phases. They improve the surgical area entrance and produce a better centralized, conservative, and cleaner cavity;[11] thus, decreasing the number of dentinal tubules exposed and reducing apical leakage.[2] Unfortunately, ultrasonic retrotips have the critical disadvantage of generating a high number of fractures during the preparation of dentine walls.[20] Peters et al.[12] demonstrated in their study that diamond-coated retrotips produced a better-quality surface with fewer cracks than cavities prepared with

Table 2. Mean values of groups, standard deviations (SD), and Kruskal-Wallis H and post-hoc multiple comparison test results

Groups							Kruskal-Wallis H test		
		n	Mean ± SD (MPa)	Median (MPa)	Min (MPa)	Max (MPa)	Average	H	p
1	Bur + MTA	20	5.04±0.76	5.18	2.84	5.93	25.35		
2	Bur + Tech Biosealer	20	4.5±1.27	4.36	2.02	7.99	19.15		
3	Bur + Biodentine	20	8.8±0.63	8.9	7.28	9.78	95.3		
4	Laser + MTA	20	9.74±0.67	9.65	8.37	10.83	124.05		
5	Laser + Tech Biosealer	20	6.43±0.55	6.51	4.99	7.3	48.1	158.56	0.001
6	Laser + Biodentine	20	10.15±0.79	10.2	8.55	11.67	138.25		
7	Ultrasonic + MTA	20	10.01±0.6	10.07	8.6	10.9	133.65		
8	Ultrasonic + Tech Biosealer	20	7.74±0.37	7.77	7.06	8.43	71.35		
9	Ultrasonic + Biodentine	20	10.83±0.62	10.82	9.92	11.85	159.3		
Total		180	8.14±2.32	8.61	2.02	11.85	**2-3 2-4 2-7 2-6 2-9 1-3 1-4 1-7 1-6 1-9 5-4 5-7 5-6 5-9 8-4 8-7 8-6 8-9 3-9**		

SD: Standard deviation, MTA: Mineral trioxide aggregate.

Table 3. Comparisons between groups using post-hoc multiple comparison tests

1	Bur + MTA									
2	Bur + Tech Biosealer	-								
3	Bur + Biodentine	+	+							
4	Laser + MTA	+	+	-						
5	Laser + Tech Biosealer	-	-	-	+					
6	Laser + Biodentine	+	+	-	-	+				
7	Ultrasonic + MTA	+	+	-	-	+	-			
8	Ultrasonic + Tech Biosealer	-	-	-	+	-	+	+		
9	Ultrasonic + Biodentine	+	+	+	-	+	-	-	+	
Groups		Bur + MTA	Bur + Tech Biosealer	Bur + Biodentine	Laser + MTA	Laser + Tech Biosealer	Laser + Biodentine	Ultrsnc + MTA	Ultrsnc + Tech Biosealer	Ultrsnc + Biodentine
		1	2	3	4	5	6	7	8	9

(+): A statistically significant difference between the groups, (-): no statistically significant difference between the groups. MTA: Mineral trioxide aggregate.

stainless steel ultrasonic retrotips. Vivan et al.[21] stated in their study that diamond-coated ultrasonic tips demonstrated cutting effectiveness and regular root-end preparation. However, more cracks were observed when they were used at high-power settings.[22] Bernardes et al.[23] found in their *in vitro* study that there were no cracks after using an ultrasonic retrotip at a medium-power setting. In light of this information, we used diamond-coated ultrasonic retrotips with an angle of 90° at a medium-power setting.

Another preparation technique used for root-end cavity preparation is the laser. There are many published laser types used in apical surgery. When laser irradiation is applied to dentin, water interfered ablation occurs, vaporizing the water content of the dental hard tissues following expansion and micro-explosions. It results in debris and the removal of the smear layer and micro-retentive irregularities by leaving a rough surface which allows for better mechanical bonding to form between the root-end filling and the dentinal walls.[24-26] Samad-Zadeh et al.[27] described in their study that the Er:YAG laser technique results in an irregular surface without a smear layer and the exposure of dentinal tubules, which leads to better penetration for the retrograde filling material on the wall of the cavity. However, this procedure can produce side effects. Melting, fissures or carbonization might occur, surrounding tissues might have cracks or pulpal temperature could increase. To overcome these drawbacks, Er:YAG and Er,Cr:YSG lasers were introduced.[24-26] In another study, the Er:YAG laser was used with an output power of 1W, and it was reported that no smear layer or debris were left.[28] In another study, lasers were used at a 1.8 W power output, and the irradiated dentin surfaces showed irregularities and roughness. They had no smear layer, and the tubules were open, which provided micro-retentive patterns.[29] Considering the above results, in our study, we chose the Er:YAG laser and used it in contact mode with the following parameters: 1.8 W 450 mj 4 Hz.

Apical microleakage is one of the reasons for the failure of endodontic treatment. Considering the success of endodontic surgery, selecting a retrograde filling material is a significant choice.[30] Below, we examine the properties of the filling materials which were part of this study.

The first filling material we used was MTA. It has various notable root-end filling characteristics: biocompatibility, a good sealing capability, high strength under compression, radiopacity, insolubility in fluids, and antibacterial effects. Inducing hard tissue formation is another advantage.[11] However, MTA has drawbacks such as having a long setting duration (2 hours 45 min) and being burdensome to manipulate.[11]

To overcome the drawbacks of MTA, new materials based on calcium silicate were introduced.[31] Biodentine and Tech Biosealer Root End are two of them. Biologically, Biodentine can seal well, it is biocompatible, and it can induce odontoblast differentiation and apposition of reparative dentin.[32] Its setting time is about 12 min.[11] It has a wide range of applications, and it is also used as a retrograde filling material in endodontic surgery.[31]

The other mentioned calcium silicate-based material is Tech Biosealer. As stated by the manufacturers, it has perfect biocompatibility, and forms a thin layer rich in calcium and phosphate on its surface, and then connects to the bone tissue through this biologically active apatite layer without a distinct boundary.[33] Therefore, Tech Biosealer is suitable for repairing perforations, it can be used for vital pulp therapy, and it is a root-end filling substance.[32]

The present study showed that the filling materials' bond strength was affected by the root-end preparation method. Independent of the cavity preparation technique, Tech Biosealer Root End showed lower bond strength, while Biodentine showed the best bond strength. When the cavity preparation techniques were considered, minimum bond strength values were seen in those cavities prepared with a bur compared to those prepared with a laser or ultrasonic tips. Mean push-out bond strength outcomes were higher in those groups prepared with the laser than in groups prepared by the bur, and the highest bond strength values in all groups were seen in the root-end samples prepared with ultrasonic tips. Bur prepared cavities might show weak bond strength values due to the cavity surface's poor condition caused by the preparation method. Compared with lasers and ultrasonic tips, rotary burs produce more debris and smear layer leftover,[24,34] weakening the contact between the filling material and cavity walls. Overall, the larger smear layer leftover produced by burs helps to explain why burs show the weakest bond strength compared to lasers and ultrasonic tips with all retrograde filling materials. In comparison, lasers and ultrasonic retrotips can remove debris and the smear layer so that retrograde cavity materials can penetrate the cavity walls.[22,24,25,33-36] This capability could explain why the bond strength values of MTA and Biodentine did not show a statistically significant difference during the comparison of Er:YAG laser and ultrasonic tips, but the bond strengths of both materials were weaker for samples prepared with the Er:YAG laser.

Open dentinal tubules and uneven surfaces lead to the increased micro-retention of the lasered dentin surface; this, in turn, increases adhesion.[26] Furthermore, sub-superficial changes occurring on the irradiated dentin have effects on adhesion. During ablation, water evaporates and causes mechanical shock. It might cause sub-superficial cracking in the dentin and might lead to dental materials adhering less to the irradiated surfaces.[37]

In our study, Biodentine showed higher bond strength values than MTA and Tech Biosealer Root End. A statistically significant difference between Biodentine and Tech Biosealer Root End was obtained. This outcome could be a result of the materials' physical and chemical properties. Biodentine's smaller particle size might cause the cement to penetrate deeper inside the dentinal tubules, improving bond strength. This feature could explain the higher values for Biodentine.[38]

The porosity of Biodentine is lower than that of MTA,[39] and the one having the most porosity is Tech Biosealer Root End.[5] This result could explain the increased bond strength of Biodentine as well. In one study, GIC, MTA, and Biodentine materials were compared concerning their marginal adaptations. The lowest marginal gaps are observed with Biodentine, which also showed good marginal adaptation. MTA followed second to Biodentine, while a very high marginal gap was observed with GIC.[39] This study shows that Biodentine and MTA have satisfactory marginal adaptation to the cavity wall, explaining the outcome of the improved bond strength of Biodentine in our study.

Study Limitations

The main limitation of this study was that, since it was performed with *in vitro* conditions, further long-term *in vivo* studies are necessary to evaluate the sealing ability of root-end material to dentine interfaces, considering the effects of blood contamination. Another clinical limitation to overcome is the large size of the handpiece of the Er:YAG laser, which makes it challenging to handle. However, in our case, the preparation procedure on extracted human teeth simplified its handling and application.

CONCLUSION

In the scope of this *in vitro* study, we can conclude that the highest bond strength values were seen in ultrasonic tip prepared cavities filled with Biodentine, and the weakest bond strength values were seen in bur prepared cavities filled with Tech Biosealer Root End. Irrespective of the root-end filling materials, bur prepared cavities showed statistically significant weaker values than the other preparation techniques ($p<0.05$). In cavities prepared with the laser and ultrasonic techniques, no statistical difference was observed between their bonding strengths ($p<0.05$). Regardless of the preparation techniques used, Tech Biosealer Root End showed the weakest bond strength. In cavities prepared with a bur, the mean bond strength value was significantly higher in Biodentine than the other materials ($p<0.05$). In the laser prepared cavities, ProRoot MTA and Biodentine's mean bond strength values were statistically higher than Tech Biosealer Root End ($p<0.05$), and in ultrasonic retrotip prepared cavities, ProRoot MTA and Biodentine's mean bond strength values were statistically significantly higher than Tech Biosealer Root End ($p<0.05$). According to these results of this study, the null hypothesis was rejected, since we found statistically significant differences in bond strength values between the different material and technique combinations.

MAIN POINTS

- The stability of the retrograde filling is essential to prevent micro-leakage. In this context, adaptations of different retrograde filling materials to dentine were compared by applying different cavity methods.
- The highest mean value occurred in the ultrasonic + Biodentine group, whereas the lowest mean value was obtained in the bur + Tech Biosealer group.
- There were no statistical differences between the cavities prepared with laser or ultrasonic retrotips and filled with MTA or Biodentine ($p>0.05$).
- As a retrograde cavity preparing technique, diamond-coated ultrasonic retrotips at medium power and Er:YAG lasers with 1.8 W power output can be used.
- Biodentine and ProRoot MTA, which are calcium silicate types of cement, can be used as a root-end cavity filling material.

ETHICS

Ethics Committee Approval: The study was performed at the Ankara University Faculty of Dentistry, and the Ethics Board approved the study protocol (approval number: 36290600/25).

Informed Consent: It was obtained.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Concept: F.C.E., Design: F.S.S., İ.Ö., Supervision: F.S.S., Fundings: B.Ç., Materials: F.C.E., Data Collection and/or Processing: F.C.E., Analysis and/or Interpretation: F.C.E., Literature Search: B.Ç., Writing: F.C.E., Critical Review: F.S.S.

DISCLOSURES

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study had received no financial support.

REFERENCES

1. Ozata F, Erdilek N, Tezel H. A comparative sealability study of different retrofilling materials. Int Endod J. 1993; 26(4): 241-5.
2. von Arx T, Walker WA 3rd. Microsurgical instruments for root-end cavity preparation following apicoectomy: a literature review. Endod Dent Traumatol. 2000; 16(2): 47-62.
3. Mente J, Leo M, Michel A, Gehrig H, Saure D, Pfefferle T. Outcome of orthograde retreatment after failed apicoectomy: use of a mineral trioxide aggregate apical plug. J Endod. 2015; 41(5): 613-20.
4. Torabinejad M, Higa RK, McKendry DJ, Pitt Ford TR. Dye leakage of four root end filling materials: effects of blood contamination. J Endod. 1994; 20(4): 159-63.
5. Prati C, Gandolfi MG. Calcium silicate bioactive cements: Biological perspectives and clinical applications. Dent Mater. 2015; 31(4): 351-70.
6. Chong BS, Pitt Ford TR. Root-end filling materials: rationale and tissue response. Endod Topics. 2005; 11: 114-30.
7. Parirokh M, Torabinejad M. Mineral trioxide aggregate: a comprehensive literature review--Part III: Clinical applications, drawbacks, and mechanism of action. J Endod. 2010; 36(3): 400-13.
8. Torabinejad M, Hong CU, McDonald F, Pitt Ford TR. Physical and chemical properties of a new root-end filling material. J Endod. 1995; 21(7): 349-53.
9. Khedmat S, Dehghan S, Hadjati J, Masoumi F, Nekoofar MH, Dummer PM. In vitro cytotoxicity of four calcium silicate-based endodontic cements on human monocytes, a colorimetric MTT assay. Restor Dent Endod. 2014; 39(3): 149-54.
10. Septodont Biodentine Endodontics Brochure. 2018. https://www.septodont.co.uk/wp-content/uploads/sites/12/2022/12/Biodentine-2018-Endo-Brochure-EN.pdf. Accessed 3 Sep 2023
11. Khandelwal A, Karthik J, Nadig RR, Jain A. Sealing ability of mineral trioxide aggregate and Biodentine as root end filling material, using two different retro preparation techniques – An in vitro study. Int J Contemp Dent Med Rev. 2015.
12. Peters CI, Peters OA, Barbakow F. An in vitro study comparing root-end cavities prepared by diamond-coated and stainless steel ultrasonic retrotips. Int Endod J. 2001; 34(2): 142-8.
13. Palma PJ, Marques JA, Casau M, Santos A, Caramelo F, Falacho RI, et al. Evaluation of Root-End Preparation with Two Different Endodontic Microsurgery Ultrasonic Tips. Biomedicines. 2020; 8(10): 383.
14. Karlovic Z, Pezelj-Ribaric S, Miletic I, Jukic S, Grgurevic J, Anic I. Erbium:YAG laser versus ultrasonic in preparation of root-end cavities. J Endod. 2005; 31(11): 821-3.

15. Krastev B, Filipov I. Simultaneous Perio-endo Surgery with Er:YAG Laser and Bone Xenograft. A Case Report. Folia Med (Plovdiv). 2020; 62(3): 631-7.

16. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol. 1971; 32(2): 271-5.

17. von Arx T, Kurt B. Root-end cavity preparation after apicoectomy using a new type of sonic and diamond-surfaced retrotip: a 1-year follow-up study. J Oral Maxillofac Surg. 1999; 57(6): 656-61.

18. Wu MK, De Gee AJ, Wesselink PR, Moorer WR. Fluid transport and bacterial penetration along root canal fillings. Int Endod J. 1993; 26(4): 203-8.

19. Nawrocka A, Łukomska-Szymańska M. Extracted human teeth and their utility in dental research. Recommendations on proper preservation: A literature review. Dent Med Probl. 2019; 56(2): 185-90.

20. Premjith, Shetty D, Kailar A, Pare S, Kumar P, Ragher M. The Effect of Root End Cavity Preparation Using Er,Cr:YSGG Laser, Ultrasonic Retrotip, and Bur on the Apical Microleakage of Retrograde Cavity Filled with MTA Plus. J Pharm Bioallied Sci. 2020; 12(Suppl 1): S299-303.

21. Vivan RR, Guerreiro-Tanomaru JM, Bosso-Martelo R, Costa BC, Duarte MA, Tanomaru-Filho M. Push-out Bond Strength of Root-end Filling Materials. Braz Dent J. 2016; 27(3): 332-5.

22. Taschieri S, Testori T, Francetti L, Del Fabbro M. Effects of ultrasonic root end preparation on resected root surfaces: SEM evaluation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2004; 98(5): 611-8.

23. Bernardes RA, de Moraes IG, Garcia RB, Bernardineli N, Baldi JV, Victorino FR, et al. Evaluation of apical cavity preparation with a new type of ultrasonic diamond tip. J Endod. 2007; 33(4): 484-7.

24. Hossain M, Nakamura Y, Tamaki Y, Yamada Y, Murakami Y, Matsumoto K. Atomic analysis and knoop hardness measurement of the cavity floor prepared by Er,Cr:YSGG laser irradiation in vitro. J Oral Rehabil. 2003; 30(5): 515-21.

25. Mohammadi Z, Jafarzadeh H, Shalavi S, Kinoshita JI, Giardino L. Lasers in Apicoectomy: A Brief Review. J Contemp Dent Pract. 2017; 18(2): 170-3.

26. Kadić S, Baraba A, Miletić I, Ionescu AC, Brambilla E, Ivanišević Malčić A, et al. Influence of different laser-assisted retrograde cavity preparation techniques on bond strength of bioceramic-based material to root dentine. Lasers Med Sci. 2020; 35(1): 173-9.

27. Samad-Zadeh A, Harsono M, Belikov A, Shatilova KV, Skripnik A, Stark P, et al. The influence of laser-textured dentinal surface on bond strength. Dent Mater. 2011; 27(10): 1038-44.

28. Takeda FH, Harashima T, Kimura Y, Matsumoto K. Comparative study about the removal of smear layer by three types of laser devices. J Clin Laser Med Surg. 1998; 16(2): 117-22.

29. Ramalho KM, Vues MM, Apel C, Meneguzzo DT, Eduardo CP, Gutknecht N. Morphological Analysis of root canal walls after Er:YAG and Nd:YAG laser irradiation: A preliminary SEM investigation. J Oral Laser Applications. 2005; 5(2): 841-5.

30. Amoroso-Silva PA, Marciano MA, Guimarães BM, Duarte MA, Sanson AF, Moraes IG. Apical adaptation, sealing ability and push-out bond strength of five root-end filling materials. Braz Oral Res. 2014; 28: S1806-83242014000100252.

31. Caron G, Azérad J, Faure MO, Machtou P, Boucher Y. Use of a new retrograde filling material (Biodentine) for endodontic surgery: two case reports. Int J Oral Sci. 2014; 6(4): 250-3.

32. Wang L, Nancollas GH. Calcium orthophosphates: crystallization and dissolution. Chem Rev. 2008; 108(11): 4628-69.

33. Gandolfi MG, Taddei P, Modena E, Siboni F, Prati C. Biointeractivity-related versus chemi/physisorption-related apatite precursor-forming ability of current root end filling materials. J Biomed Mater Res B Appl Biomater. 2013; 101(7): 1107-23.

34. Gutmann JL, Saunders WP, Nguyen L, Guo IY, Saunders EM. Ultrasonic root-end preparation. Part 1. SEM analysis. Int Endod J. 1994; 27(6): 318-24.

35. Wuchenich G, Meadows D, Torabinejad M. A comparison between two root end preparation techniques in human cadavers. J Endod. 1994; 20(6): 279-82.

36. Ekworapoj P, Sidhu SK, McCabe JF. Effect of different power parameters of Er,Cr:YSGG laser on human dentine. Lasers Med Sci. 2007; 22(3): 175-82.

37. Staninec M, Meshkin N, Manesh SK, Ritchie RO, Fried D. Weakening of dentin from cracks resulting from laser irradiation. Dent Mater. 2009; 25(4): 520-5.

38. Han L, Okiji T. Uptake of calcium and silicon released from calcium silicate-based endodontic materials into root canal dentine. Int Endod J. 2011; 44(12): 1081-7.

39. Ravichandra PV, Vemisetty H, Deepthi K, Reddy SJ, Ramkiran D, Krishna MJN, et al. Comparative Evaluation of Marginal Adaptation of Biodentine(TM) and Other Commonly Used Root End Filling Materials-An Invitro Study. J Clin Diagn Res. 2014; 8(3): 243-5.