Original Article

Impact of Different Intraorifice Barriers on Fracture Resistance of Non-Vital Bleached Teeth

M Abduljalil, B Sakalli[1], F Basmaci[2]

Department of Endodontics, Faculty of Dentistry, European University of Lefke, Lefke, Mersin10, [1]Department of Endodontics, Faculty of Dentistry, Cyprus Health and Social Sciences University, Mersin10, [2]Department of Endodontics, Faculty of Dentistry, Near East University, Mersin10, Turkey

Received: 30-Jul-2022;
Revision: 30-Sep-2022;
Accepted: 15-Nov-2022;
Published: 31-Jan-2023

ABSTRACT

Background and Aim: This study aimed to evaluate the effects of bleaching agents on the fracture resistance of endodontically treated teeth using different intraorifice barrier (IOB) materials. **Materials and Methods:** The endodontic treatment was performed for 160 mandibular premolars, and then, the teeth were divided into four groups according to the IOB: Ionoseal, Biodentine, ProRoot MTA, and TheraBase. Then, these teeth were subdivided into four subgroups (n = 10) based on the bleaching agents as distilled water (control), hydrogen peroxide 35% (HP), sodium perborate (SP), and carbamide peroxide 37% (CP). The access cavities were restored with composite resin after applying the bleaching agents for 7 days. The fracture resistance test was performed using a universal testing machine. Data were statistically analyzed, and the significance level was set at 5%. A scanning electron microscope was used to evaluate the effect of bleaching agents on the surfaces of IOBs. **Results:** The highest fracture resistance values were observed in Biodentine groups with significant differences compared to Ionoseal and ProRoot MTA (P <.05). The distilled water groups showed significantly the highest fracture resistance compared to SP and HP groups (P <.05). There was no significant difference between SP, HP, and CP groups (P >.05). It was demonstrated that the morphological surface of the intact IOBs (control) was different from the surface of IOBs treated with bleaching agents. **Conclusion:** The intracoronal bleaching procedures affected negatively the fracture resistance of the endodontically treated teeth.

KEYWORDS: *Biodentine, bleaching, fracture resistance, intraorifice barrier, therabase*

INTRODUCTION

Intracoronal bleaching is a conservative and effective treatment procedure to bleach the discolored teeth which are endodontically treated. Both thermocatalytic and walking bleach techniques are often accommodated to be used in non-vital tooth bleaching. Because of the risk of cervical root resorption, the walking bleaching technique is the most preferred method for intracoronal bleaching regarding the thermocatalytic method.[1]

Peroxides are the main substances that play an essential role in bleaching.[2] Hydrogen peroxide (HP) is the most frequently used strong oxidizing bleaching agent in different concentrations with low molecular weight and high oxidation power. HP causes an increase in dentin permeability and weakening of dental hard tissues, following the changing chemical structure of dentin and the physical properties of dental hard tissues. Thus, it has led to the investigation of alternative bleaching agents which show the same effectiveness as HP but do not have related complications. Sodium perborate (SP) mixed with water and carbamide peroxide (CP) are potentially safer alternatives to hydrogen peroxide due to low peroxide diffusion into the radicular tissues.[3-5] SP, which is accepted as urea peroxide, may be used either alone or in a combination of HP and CP to improve the capability of its bleaching effect.[6,7] CP, which is

Address for correspondence: Dr. M Abduljalil, Department of Endodontics, Faculty of Dentistry, European University of Lefke, Lefke, Mersin10, Turkey.
E-mail: mohamad_abduljalil@hotmail.com

Access this article online

Quick Response Code:

Website: www.njcponline.com

DOI: 10.4103/njcp.njcp_511_22

How to cite this article: Abduljalil M, Sakalli B, Basmaci F. Impact of different intraorifice barriers on fracture resistance of non-vital bleached teeth. Niger J Clin Pract 2023;26:95-101.

also known as urea hydrogen peroxide, is a hydrogen peroxide derivative bonded with urea.[8]

Diffusion of the bleaching agent from the pulp chamber to the radicular region is critical for endodontically treated teeth. Peroxide diffusion can make changes in the chemical structures of enamel and dentin which affect the fracture resistance, in addition to the mechanical fragility due to access cavity preparation.[1] Therefore, it would be necessary to seal intraorifice of roots with a protective base material. Intraorifice barrier (IOB) materials not only prevent peroxide diffusion into the surrounding tissues but also provide resistance against the forces that cause root fracture.[9-11]

To date, although the ideal material has not yet been understood, various materials have been proposed to be used as an intraorifice canal barrier.[12,13] For this purpose, glass ionomer cement (GIC) has the most widely recommended intraorifice barrier.[10] Nowadays, bioactive materials including Biodentine (BD; Septodont, Saint-Maur-des-Fosses, France) and ProRoot MTA (MTA; Dentsply Tulsa Dental Specialties, Memphis, TN) are utilized as a coronal barrier due to their high marginal adaptation, biocompatibility, and abilities to allow favorable seal properties.[14] TheraBase (Bisco, Schaumburg, IL, USA) is a newly produced material that is a dual-cure and self-adhesive base-liner. TheraBase releases calcium and fluoride and chemically bonds to tooth structures. It has radiopaque features, permitting easy evaluation on radiographs.[15]

To our knowledge, during the intracoronal bleaching process, there is no laboratory or clinical studies that evaluated TheraBase material in comparison to other types of intraorifice barriers. Thus, the current study aimed to assess the effects of HP, SP, and CP bleaching agents on fracture resistance using Ionoseal, Biodentine, ProRoot MTA, and TheraBase intraorifice barrier materials of endodontically treated teeth.

Materials and Methods

The present study was approved by the Scientific Research Ethics Evaluation Board with protocol number (2022/99-1478). A total of 160 mandibular second premolars were collected for this study and stored in the solution of physiologic saline. Inclusion criteria were teeth with a single canal, mature, and single apical foramen, free of carries or filling, without fracture, without calcification or resorption, and with approximate lengths (20 ± 1 mm). Preoperative radiographs for all teeth were taken, and the curvature of the roots was measured digitally according to Schneider classification.[16] The teeth that had a curvature angle of more than 5º were excluded. The criterion dimensions of the collected teeth were 6 mm for buccolingual and 8 mm for mesiodistal. To obtain standardization, teeth with a variation of more than 10% from these values were excluded.

After that, the access cavities for the teeth were prepared and standardized by a 2-mm-diameter round and fissure burs (Komet Italia Srl, Milan, Italy). Then, a K-file size 15# (Dentsply Maillefer, Ballaigues, Switzerland) was advanced inside the root canal until seeing the tip of the file from the apex, and this length was measured. The canal's working length (WL) was counted by subtracting 1 mm from the first measured length. Thereafter, root canal preparation was performed using SX, S1, S2, F1, F2, and F3 rotary files, respectively, by ProTaper Universal NiTi rotary system (Dentsply Maillefer). These files were driven by X-Smart Plus Endomotor (Dentsply Maillefer) at a 16:1 gear reduction with a hand-piece set at 250 rpm. The root canal irrigation procedures were as follows: 5.25% sodium hypochlorite between the files at a total of 20 mL per canal, 17% EDTA for 5 min at 5 mL, and 15 mL of physiological saline as a final irrigant. The root canals were dried using appropriate paper points (Dentsply Maillefer) and then were obturated with gutta-percha (Dentsply Maillefer) and AH Plus sealer (Dentsply DeTrey, Konstanz, Germany) using the lateral compaction technique. Periapical radiographs were taken for all teeth to evaluate the fineness of the root canal filling. The pulp chamber was then cleaned by a cotton pellet saturated with 70% ethanol which was used to rub the access cavity and washed with distilled water for 1 min, followed by air spray for 3 s. Thereafter, to obtain a space for the intraorifice barriers, the gutta-percha was cut off at the level of the cementoenamel junction. The coronal part of the obturation materials was removed using a heated plugger by measuring 3 mm apically of the cementoenamel junction. The measurements were achieved using a periodontal explorer and periapical radiographs.

The prepared samples were divided randomly into four groups based on the IOB as follows: group 1 (Ionoseal): The orifices in this group were sealed using injectable resin-modified glass-ionomer cement (Ionoseal; VOCO, Cuxhaven, Germany) depending on the manufacturer's guidance. Ionoseal cement was light-cured with an LED light polymerizing unit (Woodpecker; Guangxi, China) for 20 seconds; group 2 (Biodentine): According to the manufacturer's suggestions, the powder and liquid of the Biodentine were mixed and the mixture was placed into the prepared orifices; group 3 (ProRoot MTA): The powder and liquid of the ProRoot MTA were mixed depending on the manufacturer's commands and placed in the orifices as an IOB; and group 4 (TheraBase): The tip of the tube was placed into the orifice, and the mixture was injected to fill the 3 mm space in the orifice.

Subsequently, a moistened cotton pellet was placed over the IOB cement into the pulp chamber, and the access cavities were filled with a temporary filling (Cavit; 3M-ESPE, St. Paul, MN, USA). These specimens were stored for 1 week in a 37 ºC water bath to complete the setting of IOB materials. After removing the temporary filling and the cotton pellet, the samples were divided into four subgroups (n = 10) according to the bleaching agent as SP (Sodium perborate tetrahydrate powder, Merck, KGaA), HP 35% (Hydrogen peroxide gel, Opalescence Endo, Ultradent, South Jordan, UT, USA), CP 37% (Carbamide Peroxide; FGM, SC, Brazil), and distilled water as the control group.

Intracoronal bleaching procedures were performed by applying the SP bleaching agent after mixing SP powder with distilled water in a 2 g:1 ml ratio in the SP groups. The ready-to-use gels of HP and CP were injected into the pulp chamber according to the manufacturer's instructions. Then, the bleaching agent was covered with Teflon taped, and the access cavity was filled with a temporary filling. The bleaching procedure was not applied in the control groups. After that, to complete the bleaching process, the specimens were preserved in a water bath for 1 week at 37 ºC to mimic the clinical conditions. Following this period, the temporary filling and bleaching agent were removed, and the access cavities were restored using Z100 Filtek Composite Resin (3M-ESPE) and Single Bond Adhesive (3M-ESPE) depending on the manufacturer's recommendations. Then, the samples were preserved in the water bath for 3 months at 37 ºC.

Fracture test

The roots were covered by a layer of dental wax to simulate the periodontal ligament, and then the teeth were entombed in self-curing acrylic blocks allowing 2 mm of the cervical region uncovered. After that, the samples were examined in a universal testing machine (EZtest-500 N Shimadzu; Kyoto, Japan). A custom loading tool made of stainless steel with a 2-mm spherical tip was located at the center of the occlusal surface. A compressive force was applied until fracture occurred at a crosshead speed of 1 mm/min. The required forces to break each tooth were registered in newton (N).

Scanning electron microscope (SEM) evaluation

SEM was used to evaluate the influence of bleaching agents on IOB materials. Sixteen cylindrical acrylic molds (15 mm in diameter and 15 mm in high) with a central hole of 6 mm high and 3 mm diameter were prepared. These models were divided into 16 groups according to the experimental and control groups in this study. The IOB materials were placed in the bottom of the prepared holes at 3 mm thickness. The surfaces of IOB materials were smoothed with silicon carbide papers 600- and 1000-grit silicone. The techniques used for placing the materials, bleaching procedure, and incubation periods in the present study were applied for these models. After removing the temporary filling and cotton pellet, the surface of the materials was rinsed with distilled water and then dried with air for 5 s. For SEM evaluation, the surfaces of the specimens were coated with gold using a vacuum evaporator (Emitech Sputter Coater, Paris, France). Then, they were examined using SEM (JSM-6610LV; JEOL, Tokyo, Japan) under X1000 magnification.

Statistical analysis

The statistical analysis was performed using a software program (IBM SPSS Statistics, v26; IBM Corp). To verify the assumption of normality of data, Shapiro–Wilk test was used in this study. Because of the normal distribution (P >.05), parametric tests were used. Two-way ANOVA was performed to evaluate the effects of different IOB and bleaching agent materials on fracture resistance. Tukey's test was then performed for multiple comparisons, and the statistical significance level was set at 5%.

Results

The mean values of the fracture resistance and standard deviation with the results of Tukey's multiple comparison test are presented in Table 1. Depending on the statistical analysis, the IOB material (P = 0.000) and bleaching agent (P = 0.008) affected significantly the fracture resistance, while the interaction between IOB material and bleaching agent had an insignificant effect on the fracture resistance (P = 0.094). Regardless of the bleaching agent type, the highest fracture resistance values were observed in Biodentine IOB groups with significant differences compared to Ionoseal and ProRoot MTA groups (P <.05). Although the fracture resistance values of Biodentine groups were higher than those in TheraBase groups, the statistical difference was not significant (P >.05). The statistical difference between Ionoseal, ProRoot MTA, and TheraBase was insignificant (P >.05). Regardless of the IOB materials, the distilled water groups reported significantly the highest fracture resistance means compared to SP and HP groups (P <.05), while the difference between distilled water and CP groups was not significant

Table 1: Mean values of the fracture resistance and standard deviation with the results of Tukey's multiple comparison test

IOB material	Bleaching Agent				
	SP	HP	CP	Distilled Water	Total
Ionoseal	649±219	916±312	893±333	1290±336	937±373^{b}
Biodentine	1300±321	1172±403	1240±488	1299±265	1253±368^{a}
ProRoot MTA	957±160	1009±351	964±328	1122±193	1013±268^{b}
TheraBase	1090±242	986±304	1163±269	1154±196	1098±256$^{a, b}$
Total	999±334^{B}	1021±345^{B}	1065±377$^{A, B}$	1216±257^{A}	1075±339

The different superscript uppercase letters represent significant differences in bleaching agents (*P*<0.05). Different superscript lowercase letters represent significant differences in IOB materials (*P*<0.05). IOB: intraorifice barrier, SP: sodium perborate, HP: hydrogen peroxide, CP: carbamide peroxide

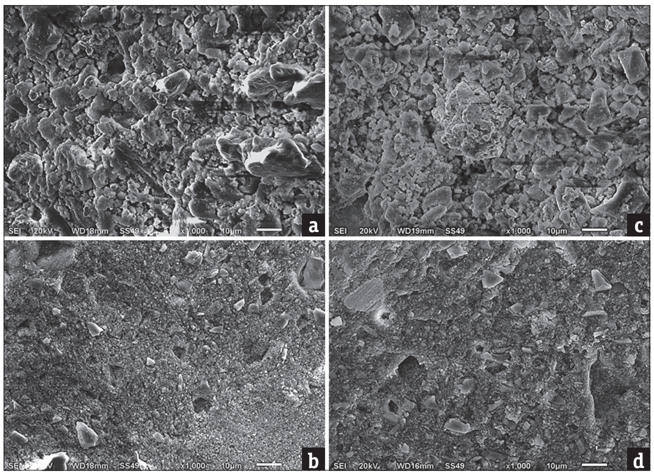

Figure 1: Scanning electron micrographs at magnifications of ×1000 showing the differences between the IOB surfaces with and without applying bleaching agents, (a) IOB without bleaching, (b-d) IOB after bleaching with HP, SP, and CP, respectively

(P >.05). The difference between SP, HP, and CP groups was statistically insignificant (P >.05).

SEM images of the effect of bleaching agents on IOB materials are presented in Figure 1. The results of SEM evaluations showed the differences between the morphological surfaces of IOB before (control) and after bleaching agents application. In general, the SEM views of the different IOB materials when using the same bleaching agent were similar. The surfaces of the IOB materials in control groups revealed needle-like crystals or clusters of globular and cubic crystals. HP and CP groups showed a honeycomb pattern with woodpecker holes on the cement surface. Globular and rod-like structures were noticed in the surfaces of IOB in SP groups. The presence of needle-like crystals was rare in the bleaching agents' groups compared to control groups.

Discussion

Recently, intracoronal bleaching techniques are used for whitening discolored endodontically treated teeth.[17] Using bleaching agents such as HP, SP, or CP could affect the structure of the tooth negatively due to the permeation of the bleaching agent into the dentinal tubules, its transmission from the cementum into the periodontal ligament tissues, and the change in pH.[18] Thus, to reduce this effect, using IOB materials such as Ionoseal, Biodentine, ProRoot MTA, and TheraBase is essential to avoid the bleaching agents into the periodontal ligaments.[19] However, this study aimed to assess the effect of HP, SP, and CP bleaching agents on those IOB materials in terms of fracture resistance because of the insufficient information about the influence of these different types of bleaching agents and IOBs in the literature.

In the current study, mandibular second premolar teeth were used because these teeth are more available and frequently extracted for orthodontic treatment. In addition, finding morphologically similar teeth of mandibular premolars could be easier than other teeth. However, it was preferred to use human teeth in this study to mimic the clinical situations which is inconsistent with previous studies which preferred to use bovine teeth.[20-22] Another reason to use mandibular second premolar teeth in this study is that locating the loading fixture at the same point for all teeth could be easier to obtain than the anterior teeth. Fixing the loading tool on the palatal surface of the anterior teeth may cause sliding of that tool on the crown surface and may affect the fracture values. Therefore, the standardization between all teeth in all groups could be higher when using mandibular second molar teeth.

The present study's results showed that the IOB material and bleaching agent affected significantly the fracture resistance, while the interaction between IOB material and bleaching agent had an insignificant impact on the fracture resistance. These findings were in agreement with the previous studies.[23] Conversely, Oskoee *et al*.[20] stated that the fracture resistance was not affected when using different types of IOB materials.

Regardless of the bleaching agent type, the Biodentine IOB groups showed the highest fracture resistance with significant differences compared to Ionoseal and ProRoot MTA groups according to this study's results. In a previous study, it was stated that Biodentine increased the force required to break the roots compared to the control groups which was in agreement with our results.[24] Also, Chauhan *et al*.[25] stated in their paper that Biodentine had the highest mean fracture resistance compared to other IOB materials. The superior properties of Biodentine could be due to the smaller particle size and uniform structure of this material, which increases the adhesion ability of Biodentine into dentinal tubules.[26] In addition, the penetration capacity within the dentinal tubules and the micromechanical anchor are other reasons. Furthermore, Biodentine has a compressive strength similar to dentin that allows for well distribution of stresses along the tooth-restoration interface during occlusal loading.[27] The weak properties of MTA to strengthen roots are probably a result of its lack of bonding to dentin and its weakness under tension forces, which is considered another reason for these findings.[28] Although glass ionomer is chemically bonding to dentin, did not improve its sealing properties over MTA.[29] Conversely, Uzunoglu *et al*.[30] stated that the difference between Biodentine and ProRoot MTA IOB groups was insignificant. However, the present study showed that the differences between Ionoseal, ProRoot MTA, and TheraBase IOB materials in terms of fracture resistance were statistically insignificant. Inconsistent with these findings, Nagas *et al*.[23] found that fracture resistance of teeth was significantly influenced by the type of IOB in which resin-modified GIC (Vitremer) groups had higher fracture resistance values than MTA groups.

The TheraBase material used in the present study as IOB material showed higher fracture resistance mean than Ionoseal and ProRoot means but lower than Biodentine groups. However, the statistical differences between TheraBase group and the other IOBs groups were insignificant. To the best of our knowledge, there is no previous study estimated the TheraBase material as IOB in terms of fracture resistance.

Regardless of IOB type, the present findings stated that the distilled water (control) groups had the highest fracture resistance values than SP, HP, and CP groups with significant differences compared to SP and HP groups. Similarly, recent studies reported that all bleaching agents and protocols reduced significantly fracture resistance compared to unbleached teeth.[17,31] Oskoee *et al*.[20] reported that the difference in HP and SP groups was significant from the control group but that with CP was insignificant which was in agreement with our findings. Also, this study presented that the differences between the three bleaching agent groups regarding fracture resistance were insignificant which was inconsistent with previous studies.[20,31] However, these results could be related to some factors. One of these factors is the mechanism of bleaching agent action on dentin tissue and the duration of exposure. HP bleaching agent has a high oxidation potential which causes the breaking down of polypeptide chains of dentin by hydroxyl radicals. Also, collagen and hyaluronic acid, which are connective tissue compositions, are decomposed, and the organic content of dentin is absorbed. These changes in the structure of dentin increase permeability and decrease its elasticity and hardness.[20] Another factor that reduces the fracture resistance after the bleaching procedure could be the acidic pH of HP which is lower than the critical peak of the enamel. This low pH can demineralize enamel hard tissue. The high concentration of sodium and chloride ions and the low concentrations of calcium and phosphate ions in the bleaching agent could be another reason for enamel's demineralization. These demineralization actions to enamel reduce the saturation of hydroxyapatite which in turn decreases the fracture resistance.[32,33]

SEM was used in the current research to evaluate the effect of bleaching agents on the surface of IOB materials. It was demonstrated that the morphological surface of the intact IOB materials (control) was different from the surface of IOB materials treated with bleaching agents. In general, the SEM views of the different IOB materials when using the same bleaching agent were similar. The SEM images showed that the needle-like crystal shape of IOBs was lost after the bleaching agent's application and a honeycomb pattern with woodpecker holes were observed. These findings were reported in similar recent studies which could be due to the removal of needle-like crystals of IOB materials after exposure to the low pH conditions of bleaching agents.[34,35] Sismanoglu *et al*.[36] stated that many defects after SEM examination, such as globular, rod-like, woodpecker holes, cracks, and capillary gaps, were revealed in the MTA cement surface compared with the control groups which was similar to the findings of this study. Similarly, Tsujimoto *et al*.[37] detected morphological differences on the surface of MTA cement according to the acidic pH of HP. They observed a noticeable reduction in the Ca/Si ratio with the release of calcium ions from the IOB surface.

In the present study, the bleaching procedure period was planned to be 7 days. Clinically, the intracoronal bleaching procedures can be repeated for 2 or even 3 sequential times up to 21 days. However, the influences of the 7-day bleaching procedure could be predominantly lower than the repeated procedures. In addition, this ex vivo study was lack of aging procedures including chewing simulation and thermal cycling with mechanical loading. Thus, these points have to be considered in future researches.

Within the limitations of this *in vitro* study, it could be concluded that the intracoronal bleaching procedures affected negatively the fracture resistance of the endodontically treated teeth. SP and HP bleaching agents reduced significantly the fracture resistance compared with the control groups. In addition, Biodentine IOB material showed the highest fracture resistance values than the other IOB materials with significant differences compared to Ionoseal and ProRoot MTA.

Acknowledgements

The authors are grateful to Assoc. Prof. Dr. Burcu Günal who provided help with the data statistical analysis of this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Attin T, Paque F, Ajam F, Lennon AM. Review of the current status of tooth whitening with the walking bleach technique. Int Endod J 2003;36:313-29.
2. Plotino G, Buono L, Grande NM, Pameijer CH, Somma F. Non Vital tooth bleaching: A review of the literature and clinical procedures. J Endod 2008;34:394-407.
3. Gökay O, Zıraman F, Çalı Asal A, Saka OM. Radicular peroxide penetration from carbamide peroxide gels during intracoronal bleaching. Int Endod J 2008;41:556-60.
4. Arı H, Üngör M. *In vitro* comparison of different types of sodium perborate used for intracoronal bleaching of discoloured teeth. Int Endod J 2002;35:433-6.
5. Lee GP, Lee MY, Lum SOY, Poh RSC, Lim KC. Extraradicular diffusion of hydrogen peroxide and pH changes associated with intracoronal bleaching of discolored teeth using different bleaching agents. Int Endod J 2004;37:500-6.
6. De Souza-Zaroni WC, Lopes EB, Ciccone-Nogueira JC, Silva RCS. Clinical comparison between the bleaching efficacy of 37% peroxide carbamide gel mixed with sodium perborate with established intracoronal bleaching agent. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;107:e43-7.
7. Chng HK, Yap AUJ, Wattanapayungkul P, Sim CPC. Effect of traditional and alternative intracoronal bleaching agents on microhardness of human dentine. J Oral Rehabil 2004;31:811-6.
8. Abouassi T, Wolkewitz M, Hahn P. Effect of carbamide peroxide and hydrogen peroxide on enamel surface: An *in vitro* study. Clin Oral Investig 2011;15:673-80.
9. Kuga MC, dos Santos Nunes Rei JM, Fabrício S, Bonetti-Filho I, de Campos EA, Faria G. Fracture strength of incisor crowns after intracoronal bleaching with sodium percarbonate. Dent Traumatol 2012;28:238-42.
10. Rotstein I, Zyskind D, Lewinstein I, Bamberger N. Effect of different protective base materials on hydrogen peroxide leakage during intracoronal bleaching in vitro. J Endod 1992;18:114-7.
11. John AD, Webb TD, Imamura G, Goodell GG. Fluid flow evaluation of Fuji Triage and gray and white ProRoot mineral trioxide aggregate intraorifice barriers. J Endod 2008;34:830-2.
12. Tselnik M, Baumgartner JC, Marshall JG. Bacterial leakage with mineral trioxide aggregate or a resin-modified glass ionomer used as a coronal barrier. J Endod 2004;30:782-4.
13. Vosoughhosseini S, Lotfi M, Shahmoradi K, Saghiri MA, Zand V, Mehdipour M, *et al*. Microleakage comparison of glass-ionomer and white mineral trioxide aggregate used as a coronal barrier in non vital bleaching. Med Oral Patol Oral Cir Bucal 2011;1:e1017-21.
14. Wattanapakkavong K, Srisuwan T. Release of transforming growth factor beta 1 from human tooth dentin after application of either ProRoot MTA or biodentine as a coronal barrier. J Endod 2019;45:701-5.
15. bisco.com. Bisco company. Available from: https://www.bisco.com/therabase-/. [Last accessed on 2022 Jun 01].
16. Schneider SW. A comparison of canal preparations in straight and curved root canals. Oral Surg Oral Med Oral Pathol 1971;32:271-5.
17. Khoroushi M, Feiz A, Khodamoradi R. Fracture resistance of endodontically-treated teeth: Effect of combination bleaching and an antioxidant. Oper Dent 2010;35:530-7.
18. Dahl J, Pallesen U. Tooth bleaching-a critical review of the biological aspects. Crit Rev Oral Biol Med 2003;14:292-304.
19. Akbulut MB, Terlemez A, Akman M, Buyukerkmen B, Guneser MB, Eldeniz AU. Tooth discoloration effects of calcium silicate based barrier materials used in revascularization and treatment with internal bleaching. J Dent Sci 2017;12:347-53.
20. Oskoee SS, Bahari M, Daneshpooy M, Ajami AA, Rahbar M. Effect of different ıntraorifice barriers and bleaching agents on the fracture resistance of endodontically treated anterior teeth. J Endod 2018;44:1731-5.
21. Bortoluzzi E, Souza E, Reis JM, Esberard RM, Tanomaru-Filho M. Fracture strength of bovine incisors after intra- radicular treatment with MTA in an experimental immature tooth model. Int Endod J 2007;40:684-91.
22. Tam LE, Kim N, De Souza GM. Effect of tooth whitening strips on fatigue resistance and flexural strength of bovine dentin in vitro. PLoS One 2017;12:e0173480.
23. Nagas E, Uyanik O, Altundasar E, Durmaz V, Cehreli ZC, Vallittu PK, *et al*. Effect of different intraorifice barriers on the fracture resistance of roots obturated with Resilon or gutta-percha. J Endod 2010;36:1061-3.
24. Yasa E, Arslan H, Yasa B, Akcay M, Alsancak M, Hatirli H. The force required to fracture endodontically roots restored with various materials as intra-orifice barriers. Niger J Clin Pract 2017;20:1237-41.
25. Chauhan P, Garg A, Mittal R, Kumar H. A comparative evaluation of fracture resistance of endodontically treated teeth using four different intraorifice barriers: An *in vitro* study. J Conserv Dent 2020;23:112.
26. Guneser MB, Akbulut MB, Eldeniz AU. Effect of various endodontic irrigants on the push-out bond strength of Biodentine and conventional root perforation repair materials. J Endod 2013;39:380-4.
27. Atmeh AR, Chong EZ, Richard G, Festy F, Watson TF. Dentin-cement interfacial interaction: Calcium silicates and polyalkenoates. J Dent Res 2012;91:454-9.
28. Tay FR, Pashley DH. Monoblocks in root canals: A hypothetical

or a tangible goal. J Endod 2007;33:391–8.

29. Barrieshi-Nusair KM, Hammad HM. Intracoronal sealing comparison of mineral trioxide aggregate and glass ionomer. Quintessence Int 2005;36:539-45.
30. Uzunoglu E, Eymirli A, Uyanik MÖ, Nagas E, Çehreli ZC. Fracture resistance of simulated immature teeth after internal bleaching procedures. Aust Endod J 2018;44:235-9.
31. Leonardo Rde T, Kuga MC, Guiotti FA, Andolfatto C, Faria-Júnior NB, Campos EA, *et al*. Fracture resistance of teeth submitted to several internal bleaching protocols. J Contemp Dent Pract 2014;15:186-9.
32. Magalhães JG, Marimoto AR, Torres CR, Pagani C, Teixeira SC, Barcellos DC. Microhardness change of enamel due to bleaching with in-office bleaching gels of different acidity. Acta Odontol Scand 2012;70:122-6.
33. Klaric E, Rakic M, Sever I, Milat O, Par M, Tarle Z. Enamel and dentin microhardness and chemical composition after experimental light-activated bleaching. Oper Dent 2015;40:E132-41.
34. Lee YL, Lee BS, Lin FH, Yun Lin A, Lan WH, Lin CP. Effects of physiological environments on the hydration behavior of mineral trioxide aggregate. Biomaterials 2004;25:787-93.
35. Kayahan MB, Nekoofar MH, Kazandağ M, Canpolat C, Malkondu O, Kaptan F, *et al*. Effect of acid- etching procedure on selected physical properties of mineral trioxide aggregate. Int Endod J 2009;42:1004-14.
36. Sismanoglu S, Yildirim-Bilmez Z, Gurcan AT, Gumustas B, Taysi M, Berkman M. Influence of intracoronal bleaching agents on the bond strength of MTA cements to composite resin and their surface morphology. Odontology 2022;110:148-56.
37. Tsujimoto M, Ookubo A, Wada Y, Matsunaga T, Tsujimoto Y, Hayashi Y. Surface changes of mineral trioxide aggregate after the application of bleaching agents: Electron microscopy and an energy-dispersive X-ray microanalysis. J Endod 2011;37:231-4.