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Original Article

The effect of bleaching agent on the compressive strength of orthodontic thermoplastic retainer materials

Ailin Ehteshami[1], Saina Omidi[1], Maede Ghasemi[2]

[1]Department of Orthodontics, Dental Research Center, Dental Research Institute, Isfahan University of Medical Sciences, Isfahan, [2]Department of Operative Dentistry, Dental Material Research Center, Dental Research Institute, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran

ABSTRACT

Background: There is an increasing desire for teeth bleching after orthodontic treatment. Therefor, this study aims to evaluate the effect of carbamide peroxide 15% and thermocycling on the compressive strength of polyethylene terephthalate glycol (PETG) thermoplastic retainer material.

Materials and Methods: In this *in vitro* study, forty samples of PETG material were thermoformed over a plastic template (10 mm × 8 mm × 2 mm). The samples were divided into four groups, with ten samples in each group. Group I served as the control, Group II was exposed to carbamide peroxide 15% (5 h daily for 14 days), Group III underwent thermocycling (5000 times), and Group IV underwent thermocycling (5000 times) followed by exposure to carbamide peroxide 15% (5 h daily for 14 days). The compressive strength of the groups was then evaluated using one-way ANOVA and Tukey's HSD tests for statistical analysis. The significance level was set to 0.05.

Results: The analysis showed a significant difference among the four groups. The compressive strength of all groups significantly decreased compared to the control group. Group II exhibited a significant decrease compared to Group III ($P = 0.003$). However, there was no significant difference between Group II and Group IV ($P = 0.191$). In addition, there was no significant difference observed between Group III and Group IV ($P = 0.308$). Group II had the lowest compressive strength (163.9 Mpa).

Conclusion: It is not recommended to use a thermoplastic retainer as a bleaching tray during the initial phase of retention. However, since there were no further harmful effects of bleaching agents observed after thermocycling, it is possible to recommend the use of a thermoplastic retainer as a bleaching tray toward the end of the retention phase.

Key Words: Bleaching agents, carbamide peroxide, orthodontic retainers, polyethylene terephthalates

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Address for correspondence:
Dr. Saina Omidi, Department of Orthodontics, Dental Research Center, Dental Research Institute, Isfahan University of Medical Sciences, Isfahan, Iran.
E-mail: sainaomidi@gmail.com

INTRODUCTION

Retention is a term used to describe the maintenance of the correct position of teeth and the prevention of age-related changes after orthodontic treatment.[1] For this purpose, appliances called retainers are used, which can be categorized as either removable or fixed. Fixed retainers are bonded to the lingual or palatal surface of teeth using a wire. Since these retainers

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are not visible, they are more esthetically pleasing. One of the advantages of fixed retainers is that they require less patient cooperation and have fewer effects on the patient's speech.[2] However, it is believed that fixed retainers may cause periodontal inflammation due to their interference with flossing.[3]

Removable retainers are typically used part time and can be easily removed, allowing patients to clean their teeth and wear them again.[4] However, they can interfere with the patient's speech.[5]

Among the commonly used removable retainers, we can mention Hawley retainers and thermoplastic or vacuum-formed retainers (VFR).[6] Thermoplastic retainers, also known as transparent retainers, have gained significant popularity in recent years.[7]

According to studies, VFR retainers exhibit high physical strength and effectively stabilize the position of teeth. They are also easy to clean and require fewer adjustments, which is why clinicians prefer them. Patients are generally more satisfied with thermoplastic retainers, as they cause less interference with speech compared to Hawley retainers.[8,9] Furthermore, the preparation technique for these retainers is relatively simple and the cost involved is relatively low.[4] The clear and transparent appearance of thermoplastic retainers makes them more esthetically appealing to patients.[10,11] In addition, thermoplastic retainers can be used as night guards for patients with mild-to-moderate dysfunction such as clenching and bruxism.[12]

However, there are some drawbacks associated with thermoplastic retainers due to their viscoelastic properties, which make them susceptible to changes in temperature, humidity, and enzyme activity. These retainers are subject to heat, chemical degradation, and mechanical forces (such as pressure, tension, and bending) while inside the mouth, which can cause structural changes to occur.[13-15]

Essix retainers are a widely used type of VFR retainer that is made of polyethylene copolymers or polypropylene (PP) polymers.[16] In a study comparing the wear resistance of different thermoplastic retainer materials, it was reported that materials based on polyethylene terephthalate glycol (PETG) exhibit higher wear resistance compared to those based on PP.[17]

In recent years, there has been an increasing demand for both bleaching and orthodontic treatments due to the growing attention to facial beauty and appearance.[18] Bleaching treatment is a viable option for teeth with internal or external discoloration.[19] There are two methods of bleaching: at home and in office. At-home bleaching, depending on whether hydrogen peroxide (HP) or carbamide peroxide is used, the treatment is performed for a period ranging from 30 min to 8 h per day over several weeks.[20,21]

The simultaneous treatment of bleaching and orthodontics, which are two main factors in dental beauty, is easily accepted by patients.[22] In addition, the retainers used in orthodontics have a suitable adaptation to the teeth to prevent teeth movement. Nowadays, there is a significant increase in the use of thermoplastic orthodontic retainers after orthodontic treatment. According to studies, thermoplastic retainers can serve as an alternative to bleaching trays.[23,24]

Several studies have been conducted in this field. In Babanouri's *et al*. study, the placement of 15% carbamide peroxide bleaching agent on PETG samples resulted in a reduction in the surface hardness of Essix sheets. Furthermore, the bleaching agent increased the surface roughness.[23]

Pascual tested PETG and PP-EPR samples using five different cleansing agents, including 3% HP. HP decreased resistance to plastic fracture growth.[25]

Bowe's study evaluated the mechanical properties of PP and PET retainers after immersion in a bleaching agent (16% carbamide peroxide). The bleaching agent had no effect on the tensile strength of PP and PET retainers.[26]

Wible tested the flexural strength, surface roughness, and light transmission of Essix Ace retainer after immersing in seven detergents. H2O2 3% demonstrated a decrease in light transmittance over time and the greatest decrease in the flexural strength of the retainer.[27]

Considering the importance of the mechanical properties of thermoplastic retainers during the retention period and the potential impact of bleaching agents on these retainers, we have decided to conduct a study to investigate the effect of 15% carbamide peroxide and thermocycling on the compressive strength of thermoplastic orthodontic retainers.

MATERIALS AND METHODS

In this *in vitro* study, 40 PETG sheet specimens (Crystal Plate, Bio Art Dental Equipment Ltda.,

São Carlos/SP, Brazil) with a thickness of 1 mm were used. To stimulate the thermoforming procedure over the tooth mold, 40 rectangular plastic templates (10 mm × 8 mm × 2 mm) were prepared. PETG sheets were thermoformed over plastic templates using a vacuum thermoforming machine (Easy Vac 2 vacuum Forming Machine, 3A Medes, Korea) according to the manufacturer's recommendation [Figure 1]. After specimens were thermoformed, excess material was removed and put them in artificial saliva and an incubator (01154, Behdad, Tehran, Iran) at 37 ˚c. The samples were randomly divided into four groups. The groups were:

i. Control
ii. Exposed to carbamide peroxide 15% (Opalescence® PF 15%, Ultradent Products Inc., South Jordan, UT, USA)
iii. III. Got 5000 cycles of themocycling
iv. IV. Got 5000 cycles of themocycling and then were exposed to carbamide peroxide 15%.

Thermocycling

PETG samples of Groups III and IV were placed in the thermocycle machine (Delta Tpo2, Nemo, Mashhad, Iran).

The samples were first placed for 30 s at a temperature of 5°C, 10 s of stopping time between the two chambers, and then for 30 s at a temperature of 55°C. Considering that retainers should be used for at least 1 year for 24 h by patients, 5000 cycles were determined to recreate the temperature and humidity of oral condition.[28]

Gel injection protocol

The samples of Group II and IV were removed from the incubator after 24 h. Then, they were removed from the template and after drying with a paper towel, bleaching gel with a thickness of 1 mm was injected into them, and they were placed on the template again [Figure 2]. The samples were exposed to bleaching gel (15% carbamide peroxide) for 5 h in incubator. After that, the samples were removed from the template and washed, dried with a paper towel, put back on the template, and placed in artificial saliva and an incubator until the next time of gel injection. The gel injection protocol was repeated every 24 h for 14 days [Figure 3].

Measuring the compressive strength of orthodontic thermoplastic retainers

A universal testing machine (Electromechanical Universal Testing Machine K – 21046, Walter + bai, Switzerland) was used for mechanical testing.

In the universal testing device, the sample was placed on the lower plate of the device and a ball-shaped head with a diameter of 3 mm and a cross-sectional area of 7.068 mm^2 was connected to the upper plate of the device. The ball head moved vertically at a speed of 1 mm/min. Force was applied to the samples until they break and the amount of this force was recorded [Figure 4].

The compressive strength was obtained using the following formula according to the load-deflection curve.

$$\text{compressive stength (MPA)} = \frac{\text{Load } (N)}{\text{cross sectional area } (mm^2)}$$

Statistical analysis

Data analysis was performed using SPSS (Version 15.0, IBM, Chicago, IL, USA). The results of this study were done with the help of one-way ANOVA and Tukey's HSD tests. $P < 0.05$ was considered statistically significant.

RESULTS

The mean compressive strength of the samples is shown in Table 1.

Considering the significant interaction between bleaching and thermocycling variables, the data were statistically analyzed using one-way ANOVA and Tukey's test. The analysis showed that there is a significant difference between the four groups ($P < 0.05$) [Table 1].

DISCUSSION

In this study, the effect of bleaching agents and thermocycling on the compressive strength of thermoplastic retainers was investigated. According to

Table 1: Mean and standard deviation of compressive strength (Mpa)

Groups	Mean (SD)	Groups			
		I	II	III	IV
I	222.4 (15.36)	-	0.005*	<0.001*	<0.001*
II	163.9 (20.86)	-	-	0.003*	0.191
III	194.0 (10.90)	-	-	-	0.308
IV	177.9 (21.44)	-	-	-	-

*Statically significant in comparison to control group (P<0.05). I: Control; II: Bleached; III: Got thermocycling; IV: Got thermocycling and bleaching; SD: Standard deviation

Figure 1: Plastic templates and samples and tubes of Carbamide peroxide 15%.

Figure 2: Gel Injection.

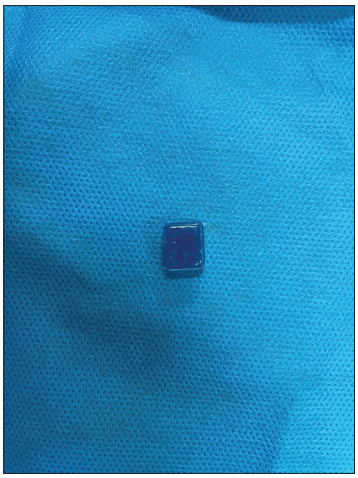

Figure 3: Carbamide peroxide 15% in samples.

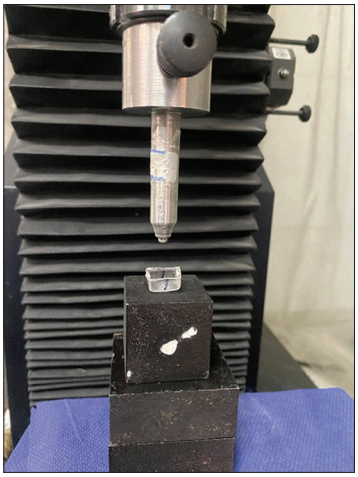

Figure 4: Measuring the compressive strength of samples.

the results, the samples in contact with the bleaching material showed a significantly lower compressive strength compared to the control group. The main cause of this reduction in strength is the presence of oxygen as an oxidizing agent in bleaching materials. Oxygen alters the structure of thermoplastic materials, affecting their mechanical properties.[29] This finding aligns with Babanouri *et al.*'s study[23] which reported a reduction in the surface hardness of PETG sheets after exposure to 15% carbamide peroxide for 2 weeks. Wible's study[27] also demonstrated a significant decrease in the flexural strength of retainers when exposed to HP.

However, in Bow's study, the tensile strength of PET and PP did not change significantly after being immersed in bleaching gel for 30 min twice a day. This discrepancy may be attributed to differences in immersion time, the type of retainer used, and the absence of oral environment stimulation.

Since patients may request bleaching treatment at any time during the retention phase, and considering the potential loss of mechanical properties in retainers over time,[30] the thermocycling process is employed to assess the effect of bleaching on compressive strength after a period of use.

The results of this study indicate that thermocycling significantly decreases the compressive strength of thermoplastic retainers.

In a study conducted by Ihssen *et al.*[31] in 2019, the effect of 1000 cycles of thermocycling on the mechanical properties of orthodontic aligners was investigated. The authors concluded that temperature changes resulting from thermocycling led to a decrease in the tensile strength and Young's modulus of the aligners.

Similarly, Iijima *et al.*[32] observed a significant decrease in the hardness and elastic modulus of PETG

sheets after 2500 cycles of thermocycling, which supports the findings of our study.

However, Dalai *et al.*[28] investigated the effect of 200 cycles of thermocycling on the mechanical properties of PETG aligners and found no impact on flexural modulus. This disparity may be attributed to the higher number of thermocycling cycles in our study.

Among the samples, Group II exhibited the lowest compressive strength (163.9 MPa). In addition, the compressive strength of Group II was significantly lower than that of Group III (P = 0.003). Therefore, when considering the importance of the retention phase at the beginning of the treatment, it is advisable to avoid using thermoplastic retainers as bleaching trays due to the significant decrease in mechanical properties. Comparing the group that received only bleach (Group II) to the group that underwent both thermocycling and bleaching (Group IV) did not yield a significant difference (P = 0.191). Similarly, no significant difference was observed between the group that received only thermocycling (Group III) and the group that underwent both thermocycling and bleaching (Group IV) (P = 0.308). This suggests that if retainers have undergone thermocycling, their compressive strength decreases to such an extent that bleaching does not have a significant impact on their compressive strength.

According to studies, in these polymers, as temperature increases, their water absorption and diffusion coefficient also increase. This leads to a phenomenon known as plasticization after water absorption. It is expected that this phenomenon is responsible for the change in the internal structure of the material. The absorption of moisture causes the disruption of secondary bonds in the chains that contribute to the material's cohesion.[33-35]

Therefore, it can be concluded that after experiencing the negative effects of the oral environment, such as temperature changes and saliva, the detrimental effects of bleaching on retainers can be overlooked. Retainers can be used as bleaching trays at the end of the retention period when the temperature changes in the mouth have already exerted their effects, provided that necessary precautions are taken.

CONCLUSION

1. The compressive strength of PETG sheets was significantly reduced by the combination of carbamide peroxide 15% and thermocycling
2. It is not recommended to use a thermoplastic retainer as a bleaching tray at the beginning of the retention phase
3. Since there were no additional destructive effects of bleaching agents after thermocycling, a thermoplastic retainer can be recommended as a bleaching tray at the end of the retention phase.

Ethical standards

The present study was approved by the Ethical Committee of Isfahan University of Medical Science, Isfahan, Iran (IR.MUI.RESEARCH.REC.1400.540).

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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