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# Effects of Sodium Hypochlorite and Hydrochloric Acid on Hardness and Surface Roughness of Orthodontic Thermoplastic Retainers

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## Abstract

**Background and Aim:** No consensus has been reached on a safe method for disinfection of orthodontic retainers without altering their physical properties. This study investigated the effects of 5.25% sodium hypochlorite (NaOCl) and 10% hydrochloric acid on hardness and surface roughness of thermoplastic orthodontic retainers.

**Materials and Methods:** In this in vitro study, 40 samples measuring 10 x 8 x 2 mm were prepared using 1-mm-thick polyethylene terephthalate glycol (PETG) Essix sheets, and randomly divided into 4 groups (n=10). In group A, the samples were immersed in 5.25% NaOCl for 15 minutes followed by immersion in 10% hydrochloric acid for 15 minutes. This process was repeated twice in group B and thrice in group C. Group D served as the control group. Surface roughness was measured by a profilometer, and hardness was measured by a Vickers hardness tester. Data were analyzed by the Kruskal-Wallis, Mann-Whitney, and Bonferroni tests (alpha=0.05).

**Results:** Immersion frequency had no significant effect on surface roughness (P=0.096). A significant difference was found in hardness among the groups (P=0.008). The mean hardness of group B was significantly lower than that of group C (P=0.004). The three test groups had no significant difference with the control group in this regard (P>0.05).

**Conclusion:** According to the results, 15 minutes of immersion in 5.25% NaOCl followed by 15 minutes of immersion in hydrochloric acid for 3 times had no significant clinical effect on the hardness and surface roughness of PETG sheets used for the fabrication of thermoplastic orthodontic retainers.

**Keywords:** Hydrochloric Acid; Sodium Hypochlorite; Orthodontic Retainers; Polyethylene Terephthalates

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## Introduction

Comprehensive orthodontic treatments are currently performed to correct multiple malocclusions with multifactorial etiologies [1]. The maintenance phase is the final stage of orthodontic treatment. It aims to keep the teeth in their correct position after treatment completion and prevent them from returning to their original position. Orthodontic retainers are prescribed for this purpose, which may be required to be used for a long time or even permanently, depending on the case [2, 3].

Two groups of orthodontic retainers are available including removable and fixed retainers. Removable retainers include the Hawley and thermoplastic retainers [4, 5]. Currently, removable retainers are more commonly used due to their low cost, superior esthetics (in the thermoplastic type), and the possibility of removal and cleaning. However, these retainers have disadvantages as well. Patient cooperation and compliance are the first requirements, especially during the first year after completion of treatment. With this in mind, it is necessary for patients to have sufficient motivation to keep using the orthodontic retainer. Also, due to the need for continuous and long-term use of these retainers, patients must maintain proper hygiene [6].

Transparent or thermoplastic retainers are made of a thin sheet of thermoplastic material with 0.25 inch thickness. They are shaped by placement of suction at a short distance from the lingual, facial, and occlusal surfaces of the teeth [2]. These retainers are well accepted due to their optimal esthetics and translucency; however, their physical properties may be affected by the oral temperature and intraoral forces. The commonly used polymers for thermoplastic retainers include polyester, polypropylene, and polyurethane [7].

Removable orthodontic appliances, including retainers, can enhance plaque accumulation. However, this effect is reported to be limited to the treatment period [8]. During orthodontic treatment, orthodontic appliances can be colonized by various microorganisms and transmit them through direct contact [7]. The purpose of immersing the appliances in disinfectants is to deactivate viruses, bacteria, and fungi [9]. Biofilm formation on the retainer creates a rough surface that can enhance the adherence of bacteria. If the surface is not properly cleaned, the plaque becomes harder, and cannot be easily removed unless by carving or brushing, which can irreversibly damage the retainer surface [10].

Removable orthodontic appliances can be cleaned mechanically or chemically. This process reduces plaque accumulation and minimizes the risk of dental caries, periodontitis, and fungal infections [3]. Evidence shows that water alone or with a toothbrush cannot completely remove the microbial biofilm. A combination of chemical and mechanical methods is recommended on a daily basis [11].

The commonly used chemicals for disinfection of oral appliances include glutaraldehyde, sodium hypochlorite (NaOCl), and chlorhexidine. Although chemical agents play an important role in removing microorganisms and microbial plaque, they may have adverse effects such as color change, reduction of strength, bending, hardness change, and increasing the surface roughness [7, 9].

Babanouri et al. [12] showed that application of 15% carbamide peroxide bleaching agent significantly increased the surface roughness and decreased the hardness of thermoplastic orthodontic retainers. Alwaeli and Alsegar [9] reported that application of disinfectant solutions slightly decreased the surface hardness of heat-polymerized resins but the difference among the groups was not significant.

NaOCl is a low-cost oxidizer with antiseptic and bleaching properties [13, 14]. This substance can remove color and bad odor [15-18]. Hydrochloric acid is another household cleaning solution which is colorless and corrosive. It is used for scaling and root planning, and also to remove stain from different surfaces. Its commonly used concentration is 10% to 12% [19].

Arruda et al. [20] immersed heat-polymerized acrylic resin samples in 0.5% NaOCl, and noticed no significant change in their hardness. Noorollahian et al. [15] reported that hydrochloric acid and NaOCl did not have a significant effect on surface hardness and roughness of auto-polymerizing acrylic resin.

Since thermoplastic retainers need to be disinfected, considering the advantages of NaOCl and hydrochloric acid, and the possibility of their adverse effects on mechanical properties of these retainers, this study aimed to evaluate the effects of 5.25% NaOCl and 10% hydrochloric acid on surface hardness and roughness of thermoplastic orthodontic retainers.

## Materials and Methods

*Ethical approval:*

This in vitro study was approved by the ethics committee of Isfahan University of Medical Sciences (IR.MUI.RESEARCH.REC.1401.067).

*Study design:*

This study was carried out in the summer of 2022 at the Faculty of Dentistry of Isfahan University of Medical Sciences and Kimia-Pazhouh Laboratory of Naghshe Jahan. In this study, 40 samples measuring 10 mm in length x 8 mm in width x 2 mm in height were prepared using 1-mm-thick polyethylene terephthalate glycol (PETG) Essix sheets.

*Research implementation:*

A rectangular piece of acrylic resin measuring 10 mm in length, 8 mm in width, and 2 mm in height was made as a template for fabrication of the samples. Essix thermoplastic material made of PETG (Crystal Plate, Bio Art Dental Equipment Ltda., Sao Carlos/SP, Brazil) with 1 mm thickness was formed around the acrylic mold, according to the manufacturer's instructions, by heating in a vacuum forming machine (3A Medes Easy Vac 2 Vacuum Forming Machine). Then, the samples were immersed in artificial saliva and incubated (01154, Behdad, Tehran, Iran) at 37°C for 24 hours. The solutions used were 5.25% NaOCl (Attack Home Bleach, Tehran, Iran) and 10% hydrochloric acid (MAN Cleanser and Descaler, Tehran, Iran). Forty samples were divided into 4 groups by simple random sampling (n=10):

A. Group A specimens was immersed in NaOCl for 15 minutes. To remove NaOCl, they were rinsed with saline for 10 seconds, and were then immersed in hydrochloric acid for 15 minutes.

B. In the second group, the above-mentioned process was repeated twice.

C. In the third group, the above-mentioned process was repeated thrice.

D. The fourth group served as the control group, and no immersion was performed.

Finally, the samples were washed with saline for 10 seconds to remove the disinfecting agents. The reason for choosing a 15-minute time for immersion was the possibility of sufficient cleaning with the selected disinfecting agents in a short period of time (16). After completing the immersion process, the samples were incubated again for 24 hours in artificial saliva at 37°C (01154, Behdad, Tehran, Iran) in order to simulate the intraoral conditions.

*Measuring the hardness:*

The hardness of the samples was measured by a Vickers hardness tester (HUATEC HVS-100, China) according to the ASTM D785 standard. For this purpose, a ball indenter with 0.5-inch diameter applied 490 millinewtons force to the samples for 10 seconds. Based on the created indentation (h), the hardness number was calculated.

*Measurement the surface roughness:*

A profilometer (Kahroba LPM-D1, Iran) was used to measure the surface roughness. The probe of the device scanned 5 mm of the surface of each sample and showed the surface roughness numerically in micrometers (µm).

*Statistical analysis:*

SPSS version 28.0 (IBM Corp., Armonk, NY, USA) was used to analyze the data. The Kolmogorov-Smirnov test showed non-normal distribution of data. Thus, comparisons were made by the Kruskal-Wallis and Mann-Whitney tests with the Bonferroni adjustment at 0.05 level of significance.

*Validity and reliability of the tool:*

The hardness test was repeated 3 times for each sample. Surface roughness was measured at 5 different points of the scanned area in each sample. For each parameter, the mean of the obtained values was calculated. If the obtained numbers were out of range, the test was repeated. For the purpose of blindness, the samples were first coded by the examiner and then tested. The analysis of the obtained data was also done by a statistical consultant blinded to the group allocation of the samples.

## Results

The mean and standard deviation of surface roughness and hardness of the groups are shown in Table 1. The results showed no significant difference in surface roughness among the study groups (P=0.096).

**Table 1**. Mean and standard deviation of surface roughness and hardness of the study samples (n=10)

| Group | Mean surface roughness± SD | Mean hardness± SD |
|---|---|---|
| **A** | 0.220±0.12 | 10.12±1.01 |
| **B** | 0.22±0.084 | 9.46±0.31 |
| **C** | 0.315±0.13 | 10.45±0.95 |
| **D** | 0.219±0.13 | 9.89±0.58 |

SD: Standard deviation

However, the results showed a significant difference in hardness among the groups (P=0.008). Pairwise comparisons by the Mann-Whitney test modified by the Bonferroni adjustment found that the mean hardness in group B was significantly lower than that in group C (P=0.004, Table 2).

**Table 2.** Pairwise comparisons of the groups regarding hardness

| Groups | A | B | C | D |
|---|---|---|---|---|
| **A** | - | 0.280 | 0.925 | 1.000 |
| **B** | - | - | 0.004* | 0.286 |
| **C** | - | - | - | 0.908 |
| **D** | - | - | - | - |

* A significant difference was seen between groups B and C.

The mean rank of surface roughness and hardness of different groups is shown in Figure 1.

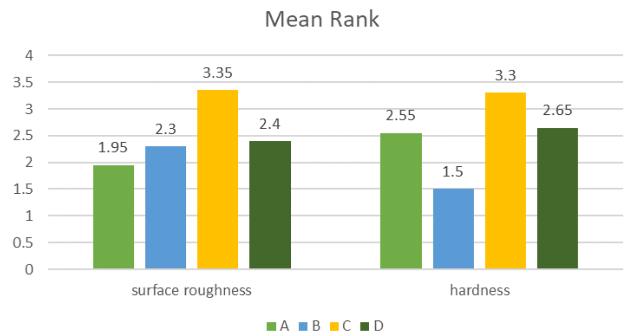


**Figure 1.** Mean rank of surface roughness and hardness of the groups

## Discussion

Orthodontic appliances interfere with the self-cleaning process of the oral cavity. This problem increases microbial accumulation and subsequently the risk of periodontal disease and dental caries. As a result, it is mandatory to keep them clean [21, 22]. Deposition of calcareous substances on removable orthodontic retainers leads to changes such as an unsightly appearance, an increase in accumulation of microbial plaque, color change, and disruption of adequate cleaning. These deposits may alter the retainer fit and even lead to unwanted tooth movement [23]. The present study evaluated the effects of 5.25% NaOCl and 10% hydrochloric acid on surface roughness and hardness of thermoplastic orthodontic retainers.

A rough surface enhances the entrapment of microorganisms and prevents complete cleaning of the surface, allowing the microorganisms to form a firmer, irreversible attachment to the surface [24, 25]. Increased surface roughness of intraoral appliances increases the adhesion of microorganisms and plaque accumulation [24].

Reducing the surface roughness can also reduce mineral deposits, color change, and unpleasant odor. Therefore, the proposed techniques for cleaning should not lead to an increase in surface roughness [26]. The maximum clinically acceptable surface roughness is 0.6 μm [27]. The mean surface roughness of the samples in the present study was lower than this value. The results of this study showed that immersing the samples in 10% hydrochloric acid for 15 minutes and in 5.25% NaOCl for 15 minutes (once, twice, and thrice) had no significant effect on their surface roughness. This result was in agreement with previous studies mentioned below:

Wible et al. conducted two studies on thermoplastic retainers made of co-polyester [28] and propylene [29] in different cleaning solutions such as 0.6% NaOCl, and showed that the tested solutions had no adverse effect on surface roughness of the tested samples. Brehove [30] did not find a significant change in surface roughness or elasticity coefficient of orthodontic retainers after their immersion in different cleaning materials. Also, Moreno et al. [31] used NaOCl solution to disinfect acrylic resins used in orthodontic retainers and found that it had no significant effect on their surface roughness. Moreover, Noorollahian et al. [15] observed no adverse effect of NaOCl and hydrochloric acid on surface roughness of acrylic resin samples of orthodontic retainers.

However, Agarwal et al. [7] observed a significant change in surface roughness of thermoplastic (polyurethane) retainers after using 0.6% NaOCl for their disinfection. Polyurethane is more susceptible to surface roughness change. In another study, Kim [10] showed that different disinfectants increased the surface roughness of thermoplastic retainers. The type of disinfecting agent (dishwashing soap, Listerine, and TheraBreath) and duration of use (16 hours of immersion) had an effective role in the obtained results.

In the present study, the surface roughness of group C was higher than other groups although the difference did not reach statistical significance. PETG has a high water absorption [32]. Several physicochemical changes can occur after water sorption in polymer materials, and their mechanical properties can be irreversibly degraded. It appears that immersion in disinfecting agents can change the nano-roughness of the polymer materials such as thermoplastic retainers [32, 33]

Hardness is another physical property investigated in the present study. It is defined as resistance against penetration and permanent deformation, and expresses the possible wear potential of an object [34, 35]. The higher the hardness of a material, the greater the resistance to wear by disinfectants, foods, and toothbrushing would be [35]. There was no significant difference between the experimental groups and the control group in hardness. But a significant difference was found between groups B and C, such that the mean hardness was 9.46 for group B (twice immersion) and 10.45 for group C (immersion for 3 times). Considering the one-unit difference in hardness between groups B and C, this difference does not appear to be clinically significant. However, this result may be due to small number of samples, and a different result may be obtained in a larger sample size. One possible explanation for the reduction in hardness may be water sorption during the disinfection process [36]. Water can act as a plasticizer, and decrease the mechanical properties of polymerized resins [37]. The small water molecules can diffuse into the polymer, progressively relaxing the polymer chains and subsequently lowering the hardness [38].

In a study conducted by Babanouri and his colleagues [12] on the effect of 15% carbamide peroxide on hardness of PETG thermoplastic samples, they noticed a decrease in hardness of the tested samples. Kim [10] also observed a decrease in hardness of thermoplastic retainers when using Listerine and TheraBreath solutions. The difference in the type of disinfectants used can justify the change in hardness of the samples. However, Arruda et al. [20] used NaOCl for acrylic samples and found no significant clinical change in their hardness. In the study by Noorollahian et al. [15], there was no change in hardness of the tested self-cure acrylic samples [15].

Considering the present results, there will be less concern about using lower concentrations of the tested disinfectants for shorter periods.

In the current study, it was not possible to use sheets with different thicknesses and materials, or to conduct more tests on more samples. Since this experimental study investigated the effect of NaOCl and hydrochloric acid on the samples in vitro, future studies are recommended on thermoplastic retainers to better evaluate the efficacy of the suggested protocol in the clinical setting. Different concentrations of disinfecting agents should also be tested with different frequency and duration of immersions in future studies.

## Conclusion

It may be concluded that 5.25% sodium hypochlorite and 10% hydrochloric acid may be safely used to properly clean orthodontic thermoplastic retainers with no adverse effect on their surface roughness or hardness. This result lowers the level of concerns regarding the use of these solutions in lower concentrations for shorter times.

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