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Effect of Ozone and Two Common Denture Cleaners on Tensile Bond Strength and Surface Hardness of a Silicone Soft Liner

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A B S T R A C T

Objectives: To evaluate the effect of ozone and two common denture cleansers on the surface hardness and bond strength of a silicone-based soft liner to acrylic denture base material.

Materials and Methods: Sixty cylindrical specimens were fabricated using heat-cured poly-methyl methacrylate denture base resin. Three millimeters of the material was ground from the midsection and filled with the soft liner. The resilient liner specimens (n=40) used for the hardness test were 10 mm in diameter and 5 mm in height. Cylindrical and disc-shaped samples were randomly divided into four groups (37°C distilled water, Corega® tablets, 0.5% sodium hypochlorite (NaOCl), and a home ozone generator). To simulate six months of denture cleansing clinically, samples were placed in their cleanser once a day for six months according to the manufacturer's instructions. All cylindrical specimens were placed under tension until failure in a universal testing machine at a crosshead speed of 5 mm/minute. For disc-shaped samples, hardness was measured using a Shore-A durometer. The results were analyzed using Kruskal-Wallis test, analysis of variance (ANOVA), and Tukey's post hoc test.

Results: The mean tensile bond strength was not significantly different among the studied groups ($P>0.05$). The mean hardness in the ozone and Corega tablet groups was significantly lower than that of the control and NaOCl groups ($P<0.05$).

Conclusion: The type of denture cleanser does not affect the tensile bond strength of silicone soft liners. Home ozone generators and cleansing tablets have less effect on the hardness of soft denture liners compared to 0.5% NaOCl.

Keywords: Ozone; Denture Liners; Tensile Strength; Surface Properties

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INTRODUCTION

Denture soft lining materials are applied as a cushion on the tissue surface of removable dentures to achieve more equal force distribution, to improve retention by engaging the undercuts, and to protect the ridge from overload [1,2]. These materials are indicated in patients with severe ridge

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resorption, thin and non-resilient mucosa, bruxism, and xerostomia, as well as over the intaglio surface of interim prostheses during implant integration [3]. There are two types of resilient soft lining materials: plasticized acrylic resins and silicone rubber.

Resilient lining materials have several drawbacks, including loss of softness, colonization by Candida albicans, and low tear strength and porosity [2,4,5]. One of the most common problems with these materials is the debonding from the denture base. Many factors can affect bond strength such as water sorption, surface primers, and denture base composition [1,2]. Gradual hardening of resilient liners is another problem that can lead to the delivery of greater occlusal forces to the underlying mucosa and increased clinical complaints [6,7].

Denture cleaning is a vital part of oral hygiene since denture is a favorable environment to harbor bacterial and fungal pathogens such as Streptococci, Candida and other microorganisms including respiratory pathogens [8]. Despite the constant introduction of new products, there is no consensus regarding the best method of denture plaque control [1,8].

Using brushes with hard bristles and too much force would cause scrapes and surface roughness in soft liners. A rough surface encourages plaque and pigment accumulation and jeopardizes aesthetics. Chemical cleaners are recommended as the method of choice, especially in elderly patients who have reduced motor-nerve capabilities to perform a mechanical cleansing technique [4,5,9].

Alkaline peroxides or percarbonates are commercially available as powders or tablets. Alkaline peroxide products consist of an alkaline component, detergent, sodium perborate, and artificial flavors. Sodium perborate dissolution produces peroxide, which in turn, breaks down and releases oxygen. The free oxygen dissolves and detaches organic residues or microorganisms while being harmless to denture material. However, peroxides are not effective when heavy calculus exists and some are incompatible with soft liners [10].

Existing in the form of liquid or gas, ozone is a powerful disinfectant against viruses, fungi, and bacteria and has recently been utilized in dentistry to disinfect cavities, root canals, and periodontal pockets [11,12]. In previous studies, it has been shown that ozone can be an effective denture cleaner [13-15]. The low concentrations of aqueous ozone, generated by home ozonators, can effectively eliminate bacteria and fungi [16]. Ozone can be far more effective when combined with mechanical methods. Compared to other chemical cleansers, ozone is a more convenient and cheaper choice [13]. Few studies have assessed the effect of ozone on the mechanical properties of soft liners. Therefore, this study aimed to compare the effect of a home ozone generator and two common denture cleansers on the surface hardness and bond strength of a silicone-based denture lining material to poly-methyl methacrylate denture base resin. The null hypothesis was that there would be no difference among the three studied denture cleansers in terms of the effect on the bond strength or hardness of resilient denture liners.

MATERIALS AND METHODS

The resilient liner in this study was a commercial silicone-based material, namely Molloplast® B (DETAX GmbH & Co. KG, Ettlingen, Germany), and the denture base material was a heat-polymerized acrylic resin (Triplex, Ivoclar Vivadent AG, Schaan, Liechtenstein). For the tensile bond strength test, 60 cylindrical-shaped acrylic resin specimens were fabricated according to the manufacturer's instructions. The specimens were prepared by investing a cylindrical resin pattern, 32 mm in height and 7 mm in diameter. Silicone rubber was placed around the resin pattern to facilitate the removal of the processed specimens from the flask. Once removed from the flask, the specimens were cut in halves using a water-cooled low-speed diamond saw (IsoMet, Buehler, IL, USA).

Next, 1.5 mm of each half was ground to provide space for a 3-mm-thick soft liner material. The acrylic specimens were placed back in the molds, and the Molloplast-B bonding agent was applied on the bonding surfaces. The resilient liner materials were then packed into space between the two blocks, trial packed, and polymerized according to the manufacturer's instructions. Before the specimens were retrieved from the denture flasks, they were left to cool at room temperature for 20 minutes.

The prepared specimens were then randomly divided into four groups (n=15) based on the cleansing treatment:

1. Control group (CG): the specimens were immersed in 37º C distilled water.
2. Sodium hypochlorite (NaOCl; SH): the specimens were immersed for 10 minutes per day in a 0.5% NaOCl solution.
3. Cleansing tablet (CT): one tablet (Glaxosmithkline, Stafford-Miller Ltd., Waterford, Ireland) was dissolved in 200 ml of warm (40±2°C) tap water. The specimens were immersed in the solution for 3 minutes per day according to the manufacturer's instructions.
4. Ozonated water (OW): the specimens were immersed in ozonated water [2.5 parts per million (ppm)] produced by a home ozone generator (ARDA, MHP1H, Iran) for 2 hours daily.

To simulate 6 months of denture cleansing, the specimens were immersed in denture cleansers daily according to the manufacturer's instructions. The specimens were then rinsed under tap water and stored in 37ºC distilled water throughout the study. For each immersion, fresh solutions of denture cleansers were provided, and distilled water was changed daily.

All cylindrical specimens were subjected to a tensile test in a universal testing machine (Santam STM-20, Tehran, Iran) at a crosshead speed of 5 mm/minute. The tensile strength was calculated using this formula: S=F/A, where S is the tensile stress (MPa), F is the maximum tensile force (N), and A is the bonded surface area (mm2). To determine the failure mode, the specimens were scrutinized under a light microscope (Dino-Lite, Taiwan) at ×40 magnification and were categorized into three groups: adhesive (the liner-acryl interface), cohesive (within the soft liner bulk), and mixed (a combination of the former). For the hardness test, 10 disc-shaped resilient liner specimens, 10 mm in diameter and 15 mm in height, were fabricated for each group by investing the wax patterns. After the elimination of the wax, the resilient lining material was packed into the flask, trial packed, and processed according to the manufacturer's instructions. The processed molds were left to cool at room temperature for 20 minutes, and the polymerized specimens were removed from the flask. A Shore-A durometer (KORI SEIKI MFG. Co., Ltd., Japan) was used to perform the Shore-A hardness test. Each disc-shaped specimen was tested at three separate points, and the mean value was appointed as the mean surface hardness. The results were analyzed using Kruskal-Wallis test for tensile bond strength while the hardness was analyzed using one-way analysis of variance (ANOVA) and Tukey's post-hoc test. The statistical significance was set at P<0.05.

RESULTS

The mean and standard deviation (SD) of the bond strength and hardness of resilient liner materials in the four groups are given in Table 1.

Table 1: Mean±standard deviation, minimum, and maximum of tensile bond strength and hardness among the groups

	Tensile bond strength (MPa)				Hardness			
Groups	**Mean±SD**	**Min**	**Max**	**P***	**Mean±SD**	**Min**	**Max**	**P#**
Control	1.53±0.17	1.27	1.82	0.13	34.12±2.49	28.34	37.17	P<0.001
Sodium Hypochlorite	1.41±0.28	0.58	1.84		35.27±2.23	31.96	38.55	
Cleansing Tablet	1.65±0.29	1.06	2.21		30.56±1.78	26.66	32.73	
Ozonated Water	1.53±0.35	0.90	2.22		31.38±2.22	27.57	34.31	

* Kruskal-Wallis test

One-way ANOVA

Table 2: Percentage of the mode of failure in the studied groups after tensile bonding test

Groups	Cohesive	Adhesive	Mixed
Control	6.7	86.7	6.7
Sodium Hypochlorite	0	100	0
Cleansing Tablet	0	86.7	13.3
Ozonated Water	0	100	0

According to the outcome of the Shapiro-Wilk analysis, the bond strength values in the experimental groups had a non-normal distribution ($P<0.05$). Based on the Kruskal-Wallis test, the mean tensile bond strength was not significantly different among the studied groups ($P>0.05$). The predominant failure mode for all experimental groups was the adhesive failure pattern (Table 2).

Table 3: Pairwise comparisons of the mean hardness

Group pairs	Mean difference	P-value
OW versus CT	-1.146	0.838
OW versus SH	3.556	0.002*
OW versus CG	2.737	0.040*
CT versus SH	4.702	<0.001*
CT versus CG	3.883	0.005*
SH versus CG	-0.819	0.838

OW: Ozonated Water, CT: Cleansing Tablet, SH: Sodium Hypochlorite, CG: Control group
*Indicates statistical significant difference

The one-way ANOVA revealed significant differences between the studied groups in terms of the mean hardness ($P<0.001$). According to Tukey's HSD (honestly significant difference) test, the mean hardness values of ozone and Corega tablets were significantly lower than that of the control and NaOCl groups ($P<0.05$; Table 3).

DISCUSSION

According to the results of this study, the type of denture cleanser does not affect the tensile bond strength between silicone-based resilient liners and acrylic denture base resin. Thus, the first null hypothesis is accepted, indicating that there would be no difference among the three studied denture cleansers in terms of the effect on bond strength.

It has been demonstrated that Corega tablets have no effect on the bond strength of soft liners [17,18] but the data regarding NaOCl are inconclusive since some studies report reduced bond strength after immersion in NaOCl [17,19] while other studies, as well as the present study, fail to prove such effect [1,18]. Mahboub et al [17] studied the effect of Corega and NaOCl solutions on tensile and shear bond strength of GC soft liners. They showed that contrary to NaOCl solution, immersion in the Corega solution did not decrease the bond strength of soft liners to acrylic resin; however, they used a higher concentration of NaOCl (2.5%) [17]. In another study by Geramipanah et al [18], four types of soft liner, including Molloplast-B, were immersed in Corega and 2.5% NaOCl and tested for tensile bond strength. The authors reported that the cleansing solution did not affect the bond strength of Molloplast-B to denture base resin. [18] This finding is consistent with the current study, but it should be mentioned that the cited study used a shorter storage time [18]. The extensive variation in the materials and methods of different studies hinders a direct comparison.

The antimicrobial activity of ozone has been recently utilized in different fields of dentistry such as restorative dentistry, endodontics, surgery, and prosthodontics [16]. It has been demonstrated that aqueous ozone can be an efficient disinfectant to eradicate Candida albicans [13]. ARDA home ozonators have been manufactured for domestic purposes. They can produce up to 2-2.5 ppm of ozonated water, and the ozone production level cannot be altered. These devices are available, relatively cheap, and easy to use and require no special training. In a recent study, the anti-fungal efficacy of this device was tested, and the results revealed that with enough exposure time (80 minutes), the colony count drops significantly [20]. The data regarding the effect of ozonated water on the mechanical properties of denture soft lining materials are scarce. Based on the results of this study, immersion in 2.5 ppm of

ozonated water for two hours per day did not affect the bond strength of Molloplast-B to acrylic denture base resin. Ekren and Ozkomur [21] studied the effect of peracetic acid and ozonated water on the tensile bond strength of two denture liners. They observed that prolonged exposure of Molloplast-B to ozonated water can adversely affect the bond strength; however, they used a higher concentration of ozonated water (4 ppm) compared to this study [21].
The results of this study revealed that home ozone generators and cleansing tablets had less effect on the hardness of soft denture liners compared to 0.5% NaOCl. Thus, the second null hypothesis, stating that there would be no difference among the three studied denture cleansers in terms of the effect on hardness, is rejected. These findings are in agreement with the results reported by Narwal [19] and Pisani et al [22] who reported that immersion in water or NaOCl solution increases the surface hardness of silicone liners. According to previous studies, surface hardness increases as storage time increases, and acrylic liners are more prone to this change than silicone liners [6,23,24].
Some studies have shown the adverse effect of cleansing tablets on the surface hardness of denture soft liners. Mohammed et al [6] and Pahuja et al [7] showed that auto-polymerized silicone soft liners gradually increase in hardness when immersed in cleansing tablets. In our study, the lowest surface hardness was related to Corega tablets. In addition to different trademarks and curing processes, the mentioned studies differed in the incubation period and storage medium from the present study. Soft liners are constantly loaded during function, and to simulate clinical conditions, thermo-cycling is a major factor that was not included in the current study [2,25]. However, since the in-vitro condition was similar for all groups, the results can be predictive of the future clinical behavior of the material.
One of the limitations of the present study was the fact that only one type of resilient lining material (silicone-based) was tested. Based on the findings of this study, the adverse effect of home ozone generators is comparable to or less than that of other cleansing methods. It is recommended to study the effect of home ozonators on other properties of denture materials such as color stability and surface roughness.

CONCLUSION

Within the limitations of this study, these conclusions can be drawn:
1. The type of tested denture cleansers does not affect the tensile bond strength between silicone-based resilient liners and acrylic denture base resin
2. Home ozone generators and cleansing tablets had less effect on the hardness of soft denture liners compared to 0.5% NaOCl.

CONFLICT OF INTEREST STATEMENT

None declared.

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