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Original Article

Disinfection of Orthodontic Elastomers and Its Effects on Tensile Strength

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Main Points

- Different changes in mechanical properties of elastomeric ligatures (EL) were found between the disinfection methods.
- Seventy percent of alcohol showed negative changes in all mechanical properties of orthodontic elastics when immersed for 30 minutes.
- Two percent glutaraldehyde did not cause significant changes in the mechanical properties of orthodontic elastics when immersed for 30 minutes.

ABSTRACT

Objective: This study aimed to investigate the effect of different disinfection protocols on the mechanical properties of orthodontic elastomeric ligatures (EL), an important issue to biosafety improvement and infection control, and to avoid cross-contamination.

Methods: A total of 120 EL were randomly divided into 6 experimental groups (n = 20) according to the disinfection method employed: group 1, EL were not immersed in a disinfectant solution (control group); group 2, EL were immersed in 2% glutaraldehyde; group 3, EL were immersed in 70% alcohol solution; group 4, EL were cleaned in an ultrasound washing (UW) machine by immersion in 0.5% enzyme detergent solution; group 5, UW procedure was performed, followed by immersion in 2% glutaraldehyde; Group 6, UW procedure was performed, followed by immersion in 70% alcohol. After disinfection, EL were subjected to a tensile strength test where the maximum strength, maximum elongation, and work at failure were determined. Data were statistically evaluated using one-way ANOVA and Dunnett's *t*-test for multiple comparisons.

Results: Statistically significant different ($P < .05$) values were found between the disinfection methods, and 70% alcohol showed negative changes in all mechanical properties of orthodontic elastomers. By contrast, 2% glutaraldehyde did not show significant alteration in mechanical properties, whereas the UW procedure showed significant alteration in maximum strength and work at failure.

Conclusion: Of the tested substances for disinfection, 2% glutaraldehyde was the only substance that did not cause significant changes in the mechanical properties of orthodontic elastics and is considered as an alternative for elastic disinfection before its use.

Keywords: Disinfection methods, orthodontics elastomers, mechanical phenomena

INTRODUCTION

Given the increasing incidence of transmissible diseases, infection control and biosafety recently came into focus, as they have not been subjected to strict criteria as they are today.[1-4] As a result, sterilization and disinfection measures are routinely adopted to avoid cross-contamination.[1,3,4] The recent spread of coronavirus disease has gripped the entire international community and caused widespread public health concerns.[5] Global efforts have been taken to prevent COVID-19 and help control its epidemic.[6] Since then, disinfection control measures have been highlighted.[3,6]

Polyurethane elastomers are widely used in orthodontics as ligatures and elastic chains.[2,7] They are structurally organized by a long polymeric chain, presenting relatively weak forces of attraction between them.[2] Elastomeric

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ligatures (EL) are mainly used to tie the archwire, which transfers the forces needed for tooth movement, to the brackets.[8,9] Their elastic properties, easiness of application, and cost-efficiency make them a very important component in orthodontic treatment.[8,9] Nevertheless, EL quickly degrades in the oral cavity and may present substantial alterations in their physical and mechanical proprieties.[8,10] The main causes of the quick degradation are related to rapid breakage of polyurethane molecular crosslinks.[11]

Numerous studies have evaluated the strength of elastomers, in terms of force delivery and rate of force decay in various environments and different testing conditions.[2,7-9,11-13] Factors such as the action of salivary enzymes, humidity of the oral environment, pH, and temperature variation, contact with masticatory forces, use of mouthwashes, and bacterial biofilm buildup have all been associated with elastomer deformation and force degradation behavior.[9,11,14]

Elastomeric ligatures are considered semi-critical dental materials that need cold sterilization since they are not resistant to heat.[1] A high level of disinfection should proceed through the destruction or inactivation of potential microorganisms and their contaminants.[1,8] This process includes cleaning, disinfection, and storage.[15] Unfortunately, elastomers undergo degradation when subjected to repeated disinfection. The effects of disinfection on the mechanical proprieties of EL have been investigated in several studies.[2,7-10,12,13,16,17] However, little information exists on the effects of disinfection methods on tensile strength.[8,9] Thus, this study aimed to assess the effect of different disinfection protocols on the mechanical properties of orthodontic EL.

METHODS

This study was conducted in the Dental Materials Laboratory of the School of Health and Life Sciences of the Pontifical Catholic University of Rio Grande do Sul (PUCRS). The Scientific Commission of Dentistry School approved its implementation, under registration number 0023/11.

A total of 120 crystal-colored EL (Morelli, Sorocaba, SP), all within the expiry date, were used. They were stored according to the manufacturer's instructions up to the time of use. The EL were randomly divided into 6 experimental groups (N = 20), according to the disinfection methods employed (Table 1): group 1, EL were not immersed in a disinfectant solution (control group); group 2, EL were immersed in 2% glutaraldehyde for 30 minutes; group 3, EL were immersed in 70% alcohol solution for 30 minutes; group 4, EL were cleaned in an ultrasound washing (UW) machine (Sercon, São Paulo, Brazil) by immersion in 0.5% enzyme detergent solution (Riozime III, Rioquímica, Rio de Janeiro, Brazil) for 10 minutes; group 5, UW procedure was performed, followed by immersion in 2% glutaraldehyde for 30 minutes; group 6, UW procedure was performed, followed by immersion in 70% alcohol solution for 30 minutes. After the UW procedure, EL were washed with purified water for 5 minutes and dried with absorbent paper. The washing and drying procedure was repeated after 30 minutes in all ligatures submitted to disinfection for the complete removal of disinfectant residues. All samples were stored in closed test tubes at room temperature for 7 days before the tensile strength test.

Table 1. Method of disinfection employed

Group	Treatment
1	Control (not immersed in any solution)
2	2% glutaraldehyde immersion for 30 minutes.
3	70% Alcohol immersion for 30 minutes.
4	Ultrasound washing for 10 minutes with enzyme detergent.
5	Ultrasound washing and 2% glutaraldehyde immersion for 30 minutes.
6	Ultrasound washing and 70% Alcohol immersion for 30 minutes.

Tensile Strength Test

The tensile strength test was performed immediately after the samples were removed from the test tubes. The tensile strength test was carried out using a pair of stainless steel hooks (0.032 inches in diameter) attached to the fixed and movable crossheads of a universal testing machine (EMIC, DL 10000 Brazil). Elastomeric ligatures were attached to the pair of hooks and stretched until fracture occurred. Each ligature was loaded in tension at a crosshead speed of 5 mm/min and load cell of 50 N, according to the recommendation of a previous study.[18] Each side of the movable crosshead was previously adjusted to ensure no initial distention. The same pair of hooks was employed in all experiments. The tensile strength test measurements were not normalized by cross-section area. The tensile and manufacturing properties of orthodontics elastomers were the same in all specimens in the present study.

The load–extension curve was recorded graphically, and the maximum strength, maximum elongation, and work at failure were determined. Data were calculated and processed by EMIC DL software. Maximum strength was defined as the maximal tension registered, obtained by the peak of the load–extension curve. The work at failure was measured as the total area under the load–extension curve from 0 to the maximum strength, corresponding to the amount of energy required to fracture the material. Maximum elongation was defined by the amount of extension necessary to reach the maximum strength, corresponding to the longitudinal distance between the 0 point and the more distant point in the load–extension curve. Maximum strength was recorded in Newton (N). Work at failure was recorded in Newton per millimeter (N/mm), whereas maximum elongation was recorded in millimeters (mm).

Statistical Analysis

An exploratory analysis was performed to evaluate data related to the studied variables. The differences among the groups were determined statistically after confirmation of normality (Kolmogorov–Smirnov) and homoscedasticity (Kendall–Stuart test). One-way analysis of variance (ANOVA) and Dunnett's *t*-test were performed to find differences between the maximum strength, maximum elongation, and work at failure. The assessed factors were the disinfection treatment and UW procedures. Data were statistically analyzed using SPSS 17.0, based on a significance level of 0.05%.

Table 2. Comparison of maximum srength and elongation and work at failure between groups with ANOVA

	Maximum Strength* Mean ± SD	Maximum Elongation** Mean ± SD	Work at Failure*** Mean ± SD
Group 1	21.39 ± 3.35	17.27 ± 0.76	16.81 ± 4.85
Group 2	22.58 ± 2.88	17.11 ± 0.60	20.78 ± 4.63
Group 3	16.94 ± 3.50	15.59 ± 1.30	14.36 ± 5.70
Group 4	21.93 ± 3.05	14.64 ± 0.54	20.32 ± 4.24
Group 5	19.93 ± 1.86	15.13 ± 0.61	17.16 ± 4.93
Group 6	22.00 ± 3.71	14.22 ± 0.51	20.56 ± 5.31
ANOVA's *P*	<.01	<.01	<.01

*Maximum strength is expressed in N. **Maximum elongation is expressed in mm. ***Work at failure is expressed in N/mm. SD, standard deviation.

RESULTS

Tensile strength test results are descriptively presented by the mean and standard deviation for each group, as shown in Table 2.

Comparison of maximum strength, elongation, and work at failure between groups are presented in Tables 2 and 3, respectively by one-way ANOVA and Dunnett's *t*-test.

Maximum Strength

According to the obtained results, a statistically significant difference ($P < .05$) in maximum strength values was found among the disinfection methods. Dunnett's Multiple comparisons showed that Group 3 had a statistically significant decrease ($P < .05$) in the maximum strength (16.94 ± 3.50 SD), when compared with the control group (21.39 ± 3.35 SD). Group 5 presented a decrease in the mean values (19.93 ± 1.86 SD) when compared with the control group, but was not statistically significant ($P > .05$). Groups 2 (22.58 ± 2.88 SD), 4 (21.93 ± 3.05 SD), and 6 (22.00 ± 3.71 SD) had a slight increase when compared with the control group (21.39 ± 3.35 SD) but not statistically significant ($P > .05$) (Tables 2 and 3).

Maximum Elongation

Statistically significant difference was found between the disinfection procedures when analyzing the maximum elongation ($P < .05$). The groups showed a decrease of elasticity and the differences were statistically significant for all groups against control, except for group 2 (Tables 2 and 3).

Work at Failure

Statistically significant differences were found between the disinfection procedures ($P < .05$). However, Dunnett's test was not able to show statistically significant differences between the disinfection procedures against the control as can be seen in Tables 2 and 3.

DISCUSSION

The longer the exposure of an item to a disinfectant, all contaminating microorganisms will be more likely inactivated.[5,8,9,19] Unfortunately, with extended exposure to disinfectant solutions, some sensitive materials used in orthodontics may more likely cause degradation of mechanical and physical properties.[10,11,20-22]

Table 3. Comparison of disinfection groups with control group by Dunnett *t*-Test

Multiple Comparisons							
						95% CI	
Variable	Group (I)	Groups (J)	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Maximum Strength	Control	Glutaraldehyde 2%	−1.19	0.98	0.83	−4.05	1.66
		Alcohol 70%	4.46*	0.98	0	1.6	7.31
		UW	−0.54	0.98	0.99	−3.39	2.32
		UW+ Alcohol 70%	−0.61	0.98	0.98	−3.46	2.24
		UW + Glutaraldehyde 2%	1.44	0.98	0.69	−1.42	4.29
Maximum Elongation	Control	Glutaraldehyde 2%	0.16	0.24	0.98	−0.55	0.86
		Alcohol 70%	1.68*	0.24	0	0.97	2.39
		UW	2.58*	0.24	0	1.87	3.29
		UW+ Alcohol 70%	3.05*	0.24	0	2.34	3.76
		UW + Glutaraldehyde 2%	2.13*	0.24	0	1.42	2.84
Work at Failure	Control	Glutaraldehyde 2%	−3.97	1.59	0.13	−8.58	0.64
		Alcohol 70%	2.45	1.59	0.63	−2.16	7.05
		UW	−3.29	1.59	0.31	−7.90	1.32
		UW+ Alcohol 70%	−3.75	1.59	0.17	−8.36	0.85
		UW + Glutaraldehyde 2%	−0.35	1.59	1	−4.95	4.26

*The mean difference is significant at the .05 level.
UW, ultrasound washing; CI, confidence interval.

Many disinfectant agents have been employed in the dental office with regard to orthodontic ligatures.[1,10] Notwithstanding, few studies have investigated the effect of washing and disinfection on the mechanical properties of orthodontic ligatures.

This study demonstrated a change in the tensile behavior of EL according to the treatment received. Similar results were found by a study evaluating the effect of 2 disinfectant solutions on 3 orthodontic ligature brands, which were exposed from 1 hour until 28 days.[9] The authors further concluded that the brand and immersion time influenced the elastic resistance of the material.[9]

Singh et al.[8] evaluated the effect of extended exposure on the tensile load at failure of different orthodontic EL to 3 disinfectant solutions. The disinfectant solutions were 1.5% glutaraldehyde, 2% glutaraldehyde, and ortho-phthalaldehyde. Compared with unexposed specimens, the behavior of all EL in terms of tensile load at failure was different according to the disinfectant solutions used.[8]

Most of the orthodontic EL currently available had similar fabrication methods.[8] However, according to Evangelista et al.,[9] significant differences exist between manufactured ligatures mainly in terms of the glass transition temperature. A higher glass transition temperature, which indicates a more rigid polymer, is associated with higher tensile strength. Tensile strength is an important property of elastic ligatures because consistent force delivery is needed to sustain full engagement of the archwires in the bracket slot for tooth movement.[8] The finding of a decrease in tensile strength after exposure to the disinfectant solution in the present study has paralleled the results of Singh et al.[8]

The 70% alcohol significantly affected the maximum strength, maximum elongation, and work at failure. These results may be attributed to the fact that synthetic elastomers (polymers) are very sensitive to the effects of free-radical generating systems, notably ozone and oxygen.[11] The exposure to free radicals results in a decrease in the flexibility and tensile strength of the polymer.[8,11] Scission of macromolecule chains is responsible for the chemical degradation in the couple bond between carbon atoms.[11]

Polyurethane elastomers have the ability to act both as donor H through the HN group or simultaneously as receptor H through the C = O group.[23] This phenomenon may be associated with superficial changes because reactivity increased with the use of 70% alcohol. Kim and Lee[24] investigated the color change in EL, and their finding suggested that alcohol solutions cause superficial chemical degradation affecting its color in the early hours of immersion by plasticizer leaching. Similar color changes were found in aesthetic EL.[25,26]

Glutaraldehyde is recognized by the Food and Drug Administration (FDA) as a high-degree disinfection agent.[19] Evangelista et al.[9] observed time dependency and progressive degradation on elastomers immersed in glutaraldehyde solution. They assumed that the active compound product and water act by plasticizing the elastic polymer and cause a polymeric chain to slip past each other. Despite that, the present study demonstrated that 2% glutaraldehyde did not significantly influence maximum strength and maximum elongation. This can be explained by the short immersion period. While in the present study the elastics were exposed to the disinfectant solution for 30 minutes, in Evangelista et al.'s[9] study, they were exposed up to 28 days.

The UW procedure with an enzyme detergent showed to affect the maximum strength and maximum elongation of orthodontic ligatures. While the maximum strength increased, the maximum elongation decreased. Those results demonstrate that a reduction in elastic property is associated with an increment in the stiffness of elastomers. Similar results were found in a study evaluating the behavior of elastomers exposed to different disinfectant solutions.[20] In the study by Nattrass et al.,[20] the loss of the strength of the elastic chain, when kept tight in different media storage, was measured after 7 days. A maximum strength increment was attributed to an increased rigidity for the incorporation of the material solution. The same cannot be observed in samples that remained without immersion. When changes in the elasticity of elastomers stored in water were assessed, it was found that the leaching process that occurred with the material was time-dependent. The exposure to liquid allowed the weakening of non-covalent bonds and subsequently degraded the elastomer.[21,27] This may be true depending on the type of agent used. Thus, cross-infection control using liquid agents should have the shortest possible immersion time. In the present study, compared with the non-UW groups, the groups that underwent longer UW in aqueous solution with detergent showed reduced elasticity. This finding suggests that the aqueous component or the chemical substances in the disinfectant solution may plasticize or cause degradation of the elastomers.

There is a need for future studies comparing different EL and time of exposure to disinfectant solutions. Time dependency and manufacturing characteristics are, without any doubt, essential to fully understand the mechanical properties of EL. However, as previously mentioned, this study mainly focused on the effect of washing and disinfection procedures for 30 minutes on the mechanical properties of orthodontic ligatures, which are important factors in this time of coronavirus pandemic.

CONCLUSION

Based on the results of this study, 2% glutaraldehyde can be used for disinfection of orthodontic EL before its use, which showed no significant influence on maximum strength, maximum elongation, and work at failure. On the contrary, 70% alcohol and UW procedure should be avoided as they significantly influence the mechanical properties of EL.

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee of the Scientific Commission of the School of Health and Life Sciences of the Pontifical Catholic University of Rio Grande do Sul (PUCRS) (Protocol number 0023/11).

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