Effect of cleaning solutions on surface roughness and flexural strength of removable orthodontic appliances

Efeito de soluções de limpeza na rugosidade superficial e resistência à flexão de aparelhos ortodônticos removíveis

Efecto de las soluciones de limpieza sobre la rugosidad de la superficie y la resistencia a la flexión de los aparatos de ortodoncia removibles

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Abstract

Purpose: Compare the roughness of self-curing acrylic resin and the flexural strength of nickel-chrome (Ni-Cr) wires of orthodontic appliances submitted to different cleaning processes. Materials and methods: Samples were made with NiCr orthodontic wires bent into a "T" loop and embedded in self-curing acrylic resin and submitted to four different cleaning procedures (n = 21): Group 1 – immersion for 15 minutes in deionized water and active oxygen-based tablet; Group 2 - immersion for 15 minutes in chlorhexidine 0.12%; Group 3 – spray with chlorhexidine 0.12% solution; and Group 4 – immersion in deionized water (control) por 15 minutes twice a day. Flexural strength of the orthodontic wire and roughness of the acrylic resin surface were determined at baseline as well as 90 and 120 days using an optical microscope. Normality of the data was determined using the Shapiro-Wilk test. The Kruskal-Wallis and Mann-Whitney tests were used for comparisons of surface roughness. ANOVA followed by Duncan's post hoc test was used for the comparison of flexural strength ($\alpha = 0.05$). Results: No significant difference in surface roughness was found, except in Group 4, in which the last reading (2.25 ± 0.89) was significantly higher than the baseline reading (1.15 ± 0.27) ($p = 0.013$). Significant reductions in the flexural strength of the wires occurred in all groups ($p = 0.002$). Conclusions: Immersion in the cleaning solutions did not alter the surface roughness of the acrylic resin but promoted a reduction in the flexural strength of the wires.

Keywords: Dental alloys; Orthodontic wires; Acrylic resin; Flexural strength, oral hygiene.

Resumo

Objetivo: Comparar a rugosidade da resina acrílica autopolimerizável e a resistência à flexão de fios de níquel-cromo (Ni-Cr) de aparelhos ortodônticos submetidos a diferentes procedimentos de limpeza. Materiais e métodos: As

amostras foram confeccionadas com fios ortodônticos de NiCr dobrados em forma de "T" e incluídos em resina acrílica autopolimerizável e submetidos a quatro diferentes procedimentos de limpeza (n = 21): Grupo 1 – imersão por 15 minutos em água deionizada e comprimido à base de oxigênio ativo; Grupo 2 - imersão por 15 minutos em clorexidina 0,12%; Grupo 3 – pulverização com solução de clorexidina 0,12%; e Grupo 4 – imersão em água deionizada (controle) por 15 minutos duas vezes ao dia. A resistência à flexão do fio ortodôntico e a rugosidade da superfície da resina acrílica foram determinadas no início, bem como aos 90 e 120 dias usando um microscópio óptico. A normalidade dos dados foi determinada pelo teste de Shapiro-Wilk. Os testes de Kruskal-Wallis e Mann-Whitney foram utilizados para comparações de rugosidade superficial. ANOVA seguida do teste post hoc de Duncan foi utilizada para a comparação da resistência à flexão (α = 0,05). Resultados: Não houve diferença significativa na rugosidade superficial, exceto no Grupo 4, no qual a última leitura (2,25 ± 0,89) foi significativamente maior que a leitura inicial (1,15 ± 0,27) (p = 0,013). Reduções significativas na resistência à flexão dos fios ocorreram em todos os grupos (p = 0,002). Conclusões: A imersão nas soluções de limpeza não alterou a rugosidade superficial da resina acrílica, mas promoveu redução na resistência à flexão dos fios.
Palavras-chave: Ligas dentárias; Fios ortodônticos; Resinas acrílicas; Resistência à Flexão; Índice de higiene bucal.

Resumen
Propósito: Comparar la rugosidad de la resina acrílica autopolimerizable y la resistencia a la flexión de alambres de níquel-cromo (Ni-Cr) de aparatos de ortodoncia sometidos a diferentes procesos de limpieza. Materiales y métodos: Las muestras fueron elaboradas con alambres de ortodoncia de NiCr doblados en forma de "T" e incrustados en resina acrílica autopolimerizable y sometidos a cuatro diferentes procedimientos de limpieza (n = 21): Grupo 1 – inmersión por 15 minutos en agua desionizada y tableta a base de oxígeno activo; Grupo 2 - inmersión durante 15 minutos en clorhexidina al 0,12%; Grupo 3 – rociado con solución de clorhexidina al 0,12%; y Grupo 4 - inmersión en agua desionizada (control) durante 15 minutos dos veces al día. La resistencia a la flexión del alambre de ortodoncia y la rugosidad de la superficie de la resina acrílica se determinaron al inicio, así como a los 90 y 120 días usando un microscopio óptico. La normalidad de los datos se determinó mediante la prueba de Shapiro-Wilk. Se utilizaron las pruebas de Kruskal-Wallis y Mann-Whitney para comparar la rugosidad de la superficie. Se utilizó ANOVA seguido de la prueba post hoc de Duncan para comparar la resistencia a la flexión (α = 0,05). Resultados: No hubo diferencia significativa en la rugosidad de la superficie, excepto en el Grupo 4, en el que la última lectura (2,25 ± 0,89) fue significativamente mayor que la lectura inicial (1,15 ± 0,27) (p = 0,013). Se produjeron reducciones significativas en la resistencia a la flexión de los alambres en todos los grupos (p = 0,002). Conclusiones: La inmersión en soluciones de limpieza no alteró la rugosidad superficial de la resina acrílica, pero promovió una reducción en la resistencia a la flexión de los alambres.
Palabras clave: Aleaciones dentales; Alambres para ortodoncia; Resinas acrílicas; Resistencia flexional; Índice de higiene oral.

1. Introduction

Interceptive orthodontic methods have minimized and even impeded the aggravation of malocclusions in the mixed dentition. However, studies have demonstrated that orthodontic appliances are capable of altering the oral microbiota, with an increase in levels of streptococci of the mutans group and lactobacilli in both the saliva and dental biofilm (Anhoury et al. 2022; Ghazal et al. 2019). This is due to the increase in surface roughness of the acrylic resin and the retention devices on removable orthodontic appliances (Al Groosh et al. 2015).

The reduction in pathogenic microorganisms on the acrylic resin and retention clasps of removable appliances is important, as these can become microbial niches (Al Groosh et al. 2015). All evidence indicates that rough acrylic resin surfaces and retention clasps are significantly more prone to the accumulation of microorganisms and the formation of biofilms than smooth surfaces (Bollen, Lambrechts & Quirynen, 1997).

The oral hygiene protocol for patients during orthodontic treatment includes verbal instructions (Scribante et al. 2017), frequency and type of brushing and the use of a dentifrice, dental floss, interdental brush and mouthwash (Kudirkaite et al. 2016). The cleaning of removable orthodontic appliances should be performed with mechanical brushing but can also be complemented with exposure to chemical agents, such as effervescent tablets and chlorhexidine (Fathi, Martiny & Jost-Brinkmann, 2015; Lessa et al. 2007; Peixoto et al. 2011; Bagatin et al. 2017).

Chemical agents can be used as daily cleaners to minimize the occurrence of biofilm on removable appliances and serve as antimicrobial agents, reaching areas that are difficult to clean by brushing alone and resulting in the complete cleaning of the orthodontic appliance (Dills et al. 1988).

However, disinfectant solutions (Badaró et al. 2017; Muscat et al. 2018) should preserve the physical and mechanical properties that compose orthodontic appliances (Maya Arbeláez et al. 2020) and not compromise the integrity of the surface in order to minimize the colonization of microorganisms and the change in color (Panariello et al. 2015). As orthodontic appliances should have a smooth surface to avoid microbial adherence and colonization (Paranhos et al. 2013) cleaning should be performed and oral microorganisms should be removed or inactivated with the use of effective cleaning methods to maintain ideal oral health (Saleh et al., 2017).

The aim of the present study was to evaluate the effect of chemical antimicrobial agents on the roughness of the acrylic resin surface and the flexural strength of orthodontic wire. The null hypothesis was that the action of effervescent tablets and a chlorhexidine 0.12% solution (immersion and spray) would not lead to changes in the surface roughness or flexural strength of self-curing resin in removable orthodontic appliances.

2. Methodology

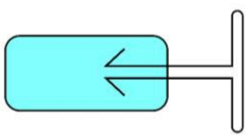
2.1 Experimental design

The study was carried out on materials for use in the manufacture of orthodontic appliances, which do not require the approval of ethics committee. The number of test specimens was established based on the results of other study (Bensel et al. 2019). The sample size was calculated considering an alpha of 0.05 and an 80% test power. As a result, 84 acrylic resin (Jet – self-curing acrylic, Artigos odontológicos clássico, Campo Limpo Paulista, Brazil) test specimens were made with nickel-chrome (Ni-Cr) orthodontic wire (0.6 mm, Dental Morelli, Sorocaba, Brazil) and randomly distributed among four groups (n = 21). As the flexural test is destructive, the specimens evaluated with regards to flexural strength were not the same as those used for the analysis of roughness.

2.2 Making of specimens

For the test specimens, a model was first made in self-curing acrylic resin (3 x 1.5 x 0.5 cm) and embedding in condensation silicone (Perfil - Coltene, Rio de Janeiro, Brazil) to obtain a silicone mold. Ni-Cr wires were bent into a standard "T" loop and placed in the silicone mold to be incorporated into the self-curing acrylic resin poured into the mold. Thus, the test bodies were composed of acrylic resin and orthodontic wire embedded in the resin (Figure 1).

Figure 1 – Sample composed of acrylic resin and orthodontic wire in standard "T" loop (Source: Authors).



Source: Authors.

Excess acrylic resin was removed with the aid of a router (Dentsply/Maillefer, Petrópolis, Brazil) on a handpiece. Polishing was performed with 180 sandpaper for wood followed by wet sanding with grits of 400 and 600. Next, a Robson brush was used with pumice stone paste and water. The specimens were than kept in deionized water at 37ºC for 48 hours for the elimination of the residual monomers of the acrylic resin and polishing residue.

2.3 Cleaning protocol

The specimens were randomly divided among four groups (n = 21). Cleaning was performed with active oxygen-based effervescent tablets (Kin Oro, Pharmakin, São Paulo, SP, Brazil) and chlorhexidine at a concentration of 0.12% (Periotrat®, Kley Hertz farmacêutica SA; Porto Alegre, Rio Grande do Sul, Brazil).

The specimens were kept in deionized water at 37ºC for 120 days. Twice a day for 15 minutes, the specimens were removed and submitted to the cleaning procedure with the chemical solutions: Group 1 – immersion for 15 minutes in 150 mL deionized water and Kin Oro active oxygen-based tablet; Group 2 - immersion for 15 minutes in 150 mL of chlorhexidine 0.12% solution (Periotrat®); Group 3 – spraying with chlorhexidine 0.12% solution; and Group 4 – immersion in 150 mL de deionized water (control). Eight-hour intervals were respected between cleaning (immersion or spraying) in all groups (12) (Table 1).

Table 1 - Distribution of groups according to cleaning material.

Groups	Cleaning material	Use	Code
Group 1	Effervescent tablets	Immersion	PI
Group 2	Chlorhexidine 0.12%	Immersion	CI
Group 3	Chlorhexidine 0.12%	Spray	CB
Group 4	Deionized water	Immersion	AI

Source: Authors.

2.4 Surface roughness of acrylic resin

A surface roughness tester (srt-6210, Cnlandtek, China) was used for the determination of the surface roughness (µm) of self-curing acrylic resin. This device has an optical probe to enable measuring the roughness (Ra) of materials. The readings were made randomly on the surface of the specimen. Five readings were obtained for each specimen and the mean was calculated. The tests were performed at a temperature of 23°C, with the diamond tip moving at a velocity of 0.50 mm/s, 4 mm of measurement length and a 2.5 mm cutoff. Readings were taken at baseline as well as at 90 and 120 days.

All specimens were examined under an optical microscope (Zeiss Axio Scope A1, Zeiss, Feldbach, Switzerland) coupled to a microscope camera (AxioCam Erc5s Rev.2, Zeiss, Feldbach, Switzerland) with magnification 20×.

2.5 Flexural strength (MPa)

The experiments were conducted in a universal testing machine (EZ-L, Shimadzu, Quioto, Japan) connected to a computer. Each wire was deflected up to 2 mm at a crosshead speed of 1 mm/minute, with a 50 N load cell. Flexural strength (MPa) was determined using the following equation: RF = 3Fd/2bh2, in which F is the load measured at the moment of fracture (N), "d" is the distance between supports (mm) and "b" and "h" are respectively with width (mm) and thickness (mm) of the specimen.

2.6 Statistical analysis

Data analysis was performed with the aid of SPSS 20.0 for Windows (SPSS Inc., Chicago, USA). The distribution of the data was determined using the Shapiro-Wilk test. The acrylic resin surface roughness data had non-normal distribution and were compared using the Kruskal-Wallis and Mann-Whitney tests. The flexural strength data had normal distribution and were compared using analysis of variance ANOVA and Duncan's post hoc test. The level of significance was set at 5% for all tests.

3. Results

Regarding surface roughness, only group 4 (evaluations at baseline and 120 days) presented a statistically significant difference (Table 2). The topographical analyses of the acrylic resin surface were performed using an optical microscope at baseline and 120 days and no significant changes in surface roughness were found.

Table 2 - Mean and standard deviation of surface roughness (µm) at different evaluation times.

Groups	Baseline	90 days	120 days	p
Group 1 (PI)	1.64 ± 0.35 ^{aA}	1.44 ± 0.20 ^{aA}	1.79 ± 1.25 ^{aA}	0.772
Group 2 (CI)	1.65 ± 0.28 ^{aA}	1.96 ± 0.27 ^{aA}	1.77 ± 1.32 ^{aA}	0.352
Group 3 (CB)	1.35 ± 0.19 ^{aA}	1.64 ±0.19 ^{aA}	2.00 ± 1.18 ^{aA}	0.372
Group 4 (AI)	1.15 ± 0.27 ^{aA}	1.83 ± 0.24 ^{bA}	2.25 ± 0.89 ^{bA}	0.013*

Same uppercase letters indicate similarity between groups. Same lowercase letters indicate similarity between evaluation times.
Source: Authors.

Regarding flexural strength, Group 4 differed from the other groups, presenting less flexural strength at 90 days. However, all solutions led to a statistically significant reduction in flexural strength at 120 days (Table 3).

Table 3 - Mean and standard deviation of flexural strength (MPa) at different evaluation times.

Groups	Baseline	90 days	120 days	p
Group 1 (PI)	219.93 ± 34.77 ^{a}	243.79 ± 14.96 ^{a}	113.97 ± 35.78 ^{bc}	0.002
Group 2 (CI)		222.90 ± 16.64 ^{a}	91.21 ± 48.68 ^{c}	
Group 3 (CB)		256.76 ± 21.85 ^{a}	75.03 ± 30.65 ^{c}	
Group 4 (AI)		153.29 ± 21.80 ^{b}	86.61 ± 40.71 ^{c}	

Same lowercase letters indicate similarity between evaluation times. Source: Authors.

4. Discussion

The ideal cleaning method for removable orthodontic appliances should be effective at removing pigments as well as organic and inorganic deposits. It should have bactericidal and fungicidal properties and be compatible with the materials of the appliance, non-toxic, inexpensive and easy to use. Changes to the surface of the acrylic resin are related to an increase in microbial colonization and caused by the action of chemical and mechanical agents used during oral hygiene. Studies have indicated surface roughness induced by chemical products used for disinfection, specially solutions containing alcohol (Bensel et al. 2019; Jo et al. 2019), quaternary ammonium compounds, acids and anionic surfactants (Hsu et al. 2020).

According to the literature, the limit established for surface roughness should be 0.2 µm to avoid the retention of microorganisms on the surface of self-curing acrylic resin (Bollen, Lambrechts & Quirynen, 1997; Passos et al. 2017). When less than 0.2 µm, other physicochemical properties of the material can play a more significant role in the development of biofilm (Papadopoulou et al. 2019). However, the values in all groups of the present study were more than 0.2 µm. Large ranges in roughness were found, with 1.15 to 2.25 µm in the deionized water group (Group 4) and 1.35 to 2.00 µm in the spray chlorhexidine 0.12% group (Group 3). These values indicate that the means between the peaks and valleys were high along the areas measured. However, in the short application time of the solutions, no significant changes were found on the surface of the acrylic resin, unlike what occurred in the control group (deionized water).

Determining the ideal antimicrobial solution that can disinfect acrylic resin without any short-term or long-term effects on the surface roughness of the material is challenging (Hsu et al. 2020). A variety of agents and specific protocols are currently recommended for the disinfection of acrylic resin, with considerable concern regarding impact of the composition of disinfectant solutions (Badaró et al. 2017) on the properties of the materials (Papadopoulou et al. 2019). Several studies have reported changes in the surface roughness of acrylic resin after disinfection with different solutions (Panariello et al. 2015; Zoccolotti et al., 2018; Machado et al. 2011). However, some authors have found that disinfection does not affect the roughness of acrylic resin in the short term (Gad et al. 2021; Al-Thobity et al. 2019), which is in agreement with the present findings. In other study also found that cleaning agents fulfill their role regarding the removal of biofilm and detritus without altering the surface of the acrylic resin (Barnabé et al. 2004). This cleaning action diminishes the accumulation of biofilm in the oral cavity, which is of fundamental importance for the cleaning of orthodontic appliances.

In this study, the flexural strength of Ni-Cr orthodontic wire was also evaluated following the use of cleaning solutions. The group submitted to deionized water (control) had lower values compared to the other groups in the first 90 days and all groups had lower flexural strength at 120 days. The smallest reduction occurred in Group 1 (effervescent tablets). These results are similar to data reported in an in vivo study (Ramalingam et al. 2008), who found no significant change in the modulus of elasticity (three-point flexion test) of orthodontic wires recovered clinically from patients using fluoride-based mouthwashes for 30 days.

The solutions used in the present in vitro study initially did not alter the characteristics of the orthodontic wire in a statistically significant manner. However, a significant reduction in flexural strength occurred with the increase in exposure time. The literature also reports a significant reduction in the modulus of flexion following treatment with mouthwashes due to the corrosion of the orthodontic wire (Hammad et al. 2012; Schiff et al. 2005).

The apparent absence of an effect of the solutions on the mechanical properties of orthodontic wire in the first evaluation period may be related to the elemental composition, as chrome offers resistance to corrosion. Chrome contributes to the surface oxide layer, which spontaneously undergoes passivation and re-passivation in the air and oral environment. These findings are compatible with data reported in previous studies, which found that stainless-steel is less susceptible to corrosion in an acidic fluoridated environment (Hammad et al. 2012; Schiff et al. 2005). With the increase in exposure time, the degradation process leads to the loss of the oxide film on the surface, exposing the underlying alloy and promoting corrosion, which weakens the alloy and may be the cause of the reduction in its mechanical properties.

One of the limitations of this study was that the experiment was performed in vitro, equivalent to 4 months of treatment, and therefore, did not represent complete oral conditions. In the oral cavity, the mechanical forces and stresses are different from the in vitro simulations, where the specimens are exposed to each condition separately. Furthermore, to simulate daily clinical practice, further studies should investigate the influence of repeated applications of disinfecting agents on orthodontic device, in different times.

5. Conclusion

Within the limitations of the present study, the findings show that the cleaning solutions evaluated did not alter the surface roughness of acrylic resin but promoted a reduction in the flexural strength of the Ni-Cr wire that composes orthodontic appliances.

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