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Short Communication

Effect of polymerization techniques and cleaning solution on flexural resistance of acrylic resin chemically activated

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The purpose of this study was to evaluate the impact of different disinfection solutions on flexural resistance of chemically-activated acrylic resin. Test pieces were made of clear acrylic resin using a rectangular mold and employing two techniques: wet polymerization under pressure (n = 20) and dry polymerization under pressure (n = 20). Test pieces were subdivided into four equal groups: distilled water (control), sodium bicarbonate, 1% sodium hypochlorite and effervescent ats. The 30-day cycling technique consisted of immersing the test pieces in 100 ml of solution for 10 min three times a day and placing them in closed containers containing artificial saliva at 37°C. Subsequently, the flexural resistance of samples was tested. Data were analyzed using two-way analysis of variance (ANOVA) with forces serving as the dependent variables and the polymerization technique and cleaning agents as independent variables. Post hoc multiple comparisons were performed using Tukey's test. There was no statistically significant difference in the flexural strength between the two polymerization techniques. The greatest flexural strength was observed for the effervescent tablets group followed by the control and 1% sodium hypochlorite groups which were statistically similar. Thus, the sodium bicarbonate solution caused the lowest flexural resistance of the test pieces.

Key words: Polymethyl methacrylate, material resistance, disinfection, orthodontic appliances.

INTRODUCTION

After completing palate expansion using a fixed appliance, a removable orthodontic appliance prevents the teeth from

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from returning to their former position (Sadowsky et al., 1994). During its use, this removable appliance must be safe without the possibility of fractures and without serving as a niche for microorganisms (Suga et al., 2005).

Studies demonstrate that orthodontic appliances can alter the oral microbiota and increase the levels of *mutans streptococci* and *lactobacilli* in saliva and dental biofilm (Mattingly et al., 1983; Jordan and Leblanc, 2002; Anhoury et al., 2002). This is particularly important because of the high risk and the prevalence of caries in orthodontic patients (Bjerklin et al., 1983; Lombardo et al., 2013). According to Ogaard (2001), 50 to 70% of the patients undergoing fixed orthodontic appliance therapy have demineralization areas on the enamel near the brackets (active white spot lesions).

In orthodontics, no effective way has been found to clean appliances without damaging them. On the other hand, efficient protocols have been published for handling and cleaning dental prostheses made from heat-cured acrylic resin, thereby maintaining the properties of the resin and making their use safe. The structure of the resin of these prostheses is similar to chemically-activated acrylic resin (Hong et al., 2009).

The materials used to manufacture removable dental appliances must also satisfy specific requirements in relation to the objectives of orthodontic treatment in particular those regarding aesthetics, resistance and strength (Fernandes et al., 2009, 2010). Chemically-activated acrylic resin is the material of choice for the manufacture of these appliances due to its specific characteristics including low cost, good adaptation, biocompatibility, easy handling, satisfactory aesthetics and satisfactory resistance against fractures (Requa-Clark, 1983).

The resin polymerization process should follow the directions of technical manuals (Requa-Clark, 1983) which generally state a wet setting. However, some laboratory technicians use a dry environment which may cause changes in the structure of the finished product influencing the use of the removable appliances during treatment.

After polymerization, the structure of chemically-activated acrylic resin can suffer the effects of external agents, whether mechanical, such as abrasive toothpastes, or chemical, such as cleaning agents (Requa-Clark, 1983; Borges et al., 2000; Silva and Seixas, 2008). The cleaning of removable appliances using a toothbrush and toothpaste is contraindicated due to the damage caused to the surface of the resin by the abrasive particles which increases its roughness and promotes the retention of biofilm (Sesma et al., 1999). Moreover, according to Diedrich (1989), brushing is ineffective to remove microorganisms from difficult-to-clean areas of appliances.

The use of antimicrobial agents is recommended for orthodontic patients to help to control the formation of bacterial biofilm (Lessa et al., 2007; Peixoto et al., 2011). Damage to acrylic structures can also be caused by the chemicals used to clean the appliances. These substances contain agents, such as sodium bicarbonate, and sodium hypochlorite that can damage or stain the surface of acrylic resin, as well as promote leaching of low-molecular-weight components, thereby increasing the roughness and a possible buildup of microorganisms on the surface (Budtz-Jorgensen, 1979; Asad et al., 1993; Neppelenbroek et al., 2005).

Thus, the production of removable appliances and cleaning and disinfection protocols should be standardized using procedures that do not weaken the structure of the resin or increase the buildup of pathogen microorganism biofilm on their surface. Thus, the aim of this work was to evaluate the effect of the use of different disinfection solutions on the flexural resistance of chemically-activated acrylic resin produced using two polymerization techniques.

The null hypothesis to be tested is that there are no differences between the polymerization techniques or the cleaning and disinfection protocols of removable appliances made with chemically-activated acrylic resin as proposed in this study.

MATERIALS AND METHODS

Forty test pieces of chemically-activated acrylic resin were made with clear self-curing acrylic resin using 2.5 parts of the polymer to 1.0 part of monomer according to the manufacturer's recommendations (JET ®, Classic, Dental Products, São Paulo, Brazil, batch number 040508).

A rectangular mold was used to create the 65 × 10 × 2.5 mm test pieces for three-point flexural strength testing as specified in paragraph 12 of the norms of the American Dental Association (ADA, 1975) specifications for denture base polymers. Thus, to produce these test pieces, slightly larger (67 × 12.60 × 3.00 mm) stainless steel metal molds were made so that the test piece could be leveled without the finished piece being too small. The final size was measured using a digital caliper (Mitutoyo®, Japan).

Test pieces were made using the following two techniques: wet polymerization (n = 20) involving immersion in pressurized water (40 psi) at 40°C for 20 min in a semiautomatic electric cooker (Metal Vander ®, Piracicaba, São Paulo, Brazil) and dry polymerization (n = 20) under pressure (40 psi) for 20 min without water in the same semiautomatic electric cooker. The data size was defined following the study of Ghaffari et al. (2014).

The two groups of test pieces (wet and dry polymerization) were further divided into four subgroups (n = 5) depending on the disinfectant solution to be used in the cleaning cycle: control group (distilled water); sodium bicarbonate group (20 g of sodium bicarbonate diluted in 200 ml of distilled water); 1% sodium hypochlorite group (Milton Liquid, Biodynamic SA, Ibiporã, Brazil) and effervescent tablets group (Corega Tabs®, GlaxoSmithKline, Rio de Janeiro, Brazil).

The 30-day cleaning cycle consisted of placing the test pieces in a container of artificial saliva at 37°C in a bacteriological incubator and immersing them in 100 ml of the disinfectant solutions for 10 min three times per day (8:00 a.m., 1:00 p.m. and 8:00 p.m.). The artificial saliva and disinfectant solutions were changed after each procedure.

Table 1. Results of flexural strength test in megapascals comparing the two polymerization techniques and cleaning agents.

Disinfectant	Polymerization	
	Wet	Dry
Control	67.31 (9.59)	67.99 (7.80)
Effervescent	76.59 (11.25)	69.18 (2.86)
Hypochlorite	71.09 (8.69)	68.55 (7.48)
Bicarbonate	62.58 (5.34)	64.08 (3.94)

Mean (standard deviation).

At the end of this period, the three-point flexural strength test was performed in an EMIC DL3000 universal testing machine calibrated with a 100-kg load cell, a crosshead speed of 5 mm/min and at 37°C. For this, the test pieces were placed on two metal supports and an axial force was applied equidistant from these two points until the test piece broke. The force needed to break the test piece was recorded in megapascal (MPa).

Statistical analysis

Descriptive statistics including mean values and standard deviation were calculated for the flexural strength and compared between the two polymerization techniques and different cleaning agents using two-way analysis of variance (ANOVA), followed by Tukey's post-hoc test. An alpha-error of 5% was considered acceptable.

RESULTS

Table 1 presents the means and standard deviation of the flexural strength tests of the two polymerization techniques and different cleaning agents. The results of this first analysis showed no statistically significant difference for flexural strength between the two polymerization techniques independent of the cleaning agent (Table 1).

On considering the possibility of an interaction between the polymerization techniques and cleaning agents, an independent analysis of these different conditions was carried out (Table 2). When the types of cleaning solution in isolation were analyzed, a significant difference (p-value < 0.001) was found between cleaning solutions; hence, Tukey's test was applied.

On comparing the cleaning agents regardless of the method of polymerization, sodium bicarbonate solution presented the lowest flexural strength, followed by the control and sodium hypochlorite groups with the highest flexural strength being found using effervescent tablets (Table 3).

DISCUSSION

On preparing chemically-activated acrylic resin, the manner in which the components are mixed together can lead to a lack of structural uniformity (Eliades and Brantley, 2000), and greater absorption of water (Dogan et al., 1995) that affect the mechanical properties of the polymers. Thus, irregularities in the mixture may favor porosity which when present on the surface of the appliance make daily cleaning difficult with the retention of residues and the development of biofilm.

According to the ISO standard 1567, a minimum flexural strength of 60 MPa is necessary for self-curing acrylic resins (American Dental Association Specifications n° 12 for denture base polymers, 1975). The flexural strength values obtained for some test pieces cleaned using sodium bicarbonate solution were lower than this unlike the flexural strength for the other cleaning agents.

According to this study, there were no statistically significant differences between the polymerization techniques (dry or wet), which leads us to believe that this is not so important.

The use of effervescent tablets is recommended to clean intra- and extra-oral acrylic resin prostheses (Goiato et al., 2010) and removable orthodontic appliances (Eichenauer et al., 2013). When these tablets are dissolved in water they form an alkaline peroxide solution. According to previous studies, effervescent tablets basically function by releasing oxygen which detaches food fragments and light stains (Oliveira et al., 2006). Therefore, using these denture cleansers can cause hydrolysis and decomposition of polymerized chemically-activated acrylic resin (Hong et al., 2009). Consequently, one might think that the detachment of fragments would increase the porosity of the material but this does not interfere in the strength, as this group had the highest flexural resistance. The true effects of aging should be investigated in future studies.

The results of this study indicate that there is no significant difference between disinfectants and polymerization methods in the study period in respect to the flexural resistance of the test pieces. Goiato et al. (2010), on studying the action of disinfectants on heat-activated acrylic resin did not observe any influence of disinfections with respect to the flexural resistance either.

Although, no significant negative effects on flexural strength were found with the effervescent tablets and 1% sodium hypochlorite solutions used in this study; a significant negative effect was identified with sodium bicarbonate solution (Table 3). The reason for this was not found in the literature; however, it is believed that the high pH of about 8 (Cunha, 2001) may damage the acrylic resin structure.

The disinfection and storage procedures of the laboratory in this study were not exactly the same as in other study protocols; although since there are few studies

Table 2. Results of flexural strength test comparing two factors: polymerization technique and cleaning agents

Variable	df	SS	MS	F	p-value
Polymerization	1	37.675	37.675	0.651	0.426
Disinfectant	3	484.031	161.344	2.789	0.056
Polymerization × disinfectant	3	122.542	40.847	0.706	0.555
Error	32	1851.345	57.855	-	-
Total	39	2495.593	-	-	-

df: Degree of freedom; SS: sum of squares; MS: mean square. *p-value < 0.05.

Table 3. Results of flexural strength test in megapascals for each disinfectant agent regardless of the type of polymerization.

Disinfectant	Mean flexural strength
Control	67.65 (8.25)^{AB}
Effervescent	72.88 (8.67)^{A}
Hypochlorite	69.82 (7.76)^{AB}
Bicarbonate	63.33 (4.49)^{B}

Mean value (standard deviation). Different capital letters in the column denote statistically significant differences (p-value < 0.05).

studies on chemically-activated acrylic resin for orthodontic appliances, there are many differences between those that do exist. It is important to note that several factors can influence the flexural resistance of acrylic resin, including the components used, particles in the environment (Raizada and Rani, 2007), porosity associated to the technique (Canadas et al., 2010) and surface flaws of the appliance (Pavarina et al., 2003).

Conclusively, the polymerization technique (wet or dry pressure) does not affect the flexural resistance of chemically-activated acrylic resin. However, there were differences in the flexural strength between the different cleaning solutions with sodium bicarbonate solution producing values lower than what is considered the minimum for chemically-activated acrylic resin.

Conflict of interests

The authors declare that they have no competing interests

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