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Effect of Thermal and Mechanical Cycles on the Hardness and Roughness of Artificial Teeth

Research Article

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Abstract

Aims: In this study the effects of thermal and mechanical cycles on the hardness and roughness of artificial teeth were evaluated.

Materials and Methods: Specimens were prepared and stored in distilled water at 37ºC for 48 hours (n=10). The hardness and roughness readings were made in the following time intervals, according to each group:G1: after specimen storage in distilled water at 37°C for 48 hours; G2: after 600.000 constant mechanical cycles; G3: after 1.200.000 constant mechanical cycles; G4: after 2.500 thermal cycling baths, alternated between hot water (55°C) and cold water (5°C) and G5: after 5.000 thermal cycling baths, alternated between hot water (55°C) and cold water (5°C). After cycling and storage procedures, the specimens of each group were submitted to surface roughness and hardness readouts. Statistical evaluation was performed by three-way analysis of variance, complemented by the Tukey multiple comparisons of means test. The level of significance adopted was 5%. There was no significant difference between G1, G4 and G5 as regards mean roughness of different brands of artificial teeth. Groups G2 and G3 showed higher mean roughness values, and generally equivalent values in all time intervals, except for Trilux (G3> G2). Significant differences in hardness values were observed in different brands of artificial teeth, and differences in values after thermal and mechanical cycling.

In conclusion, our findings suggest that thermal cycling did not change the roughness of the artificial teeth tested, but after the mechanical cycling the roughness values increased. Thermal and mechanical cycling influenced the hardness of the artificial teeth tested.

Keywords: Artificial Teeth; Hardness; Roughness; Thermal Cycling; Mechanical Cycling.

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Introduction

The use of artificial teeth with better physical and mechanical properties is essential to obtain satisfactory and lasting results in the oral rehabilitation of partially or totally edentulous patients. Indeed, the selection of artificial teeth with better properties helps to maintain maximum intercuspal occlusion, masticatory efficiency, occlusal vertical dimension, occlusal stability, and esthetics of complete and partial dentures. In these oral rehabilitation treatments, the artificial teeth mat be made of porcelain, conventional acrylic resin or improved acrylic resin. Among these types of teeth, artificial porcelain teeth are recognized for their superior qualities of longevity, high stiffness and abrasion resistance, in comparison with acrylic resin teeth. However, they are very fragile, and more likely to fracture. In addition, the hardness of porcelain material results in a more difficult occlusal adjustment and may result in cracks [22]. By contrast, acrylic resin teeth have high resilience, improved wear resistance, high ductility, they facilitate occlusal adjustment, but have lower fracture strength and low resistance to abrasion [13].

Irrespective of the choice of material, the surface hardness of artificial teeth in removable partial or complete dentures may be altered by individual oral hygiene methods, and functional friction. Therefore, it is important for artificial tooth surfaces to be resistant to abrasion. Among the mechanical properties, hardness is an important property related to abrasion resistance [1, 30]. In 2012, Campanha et al. [6] evaluated the effect of long-term disinfection procedures on the hardness of acrylic resin denture teeth and concluded that the different results as regards hardness were dueto differences in the composition of the material used to fabricate artificial teeth. In addition, Stober et al. [24] observed that the highest hardness values were found for artificial teeth made of composite resin with addition of inorganic particles in a polymer matrix.

Surface roughness is characterized by irregularities on the surface of the material, resulting from manufacturing processes, and the mechanical action of brushing or chewing. The presence of these irregularities may have important clinical implications since they favor the adhesion and colonization of microorganisms [2]. Bacterial adhesion and consequent formation of dental plaque on the surface of artificial teeth result in staining and compromised aesthetic rehabilitation. Color stability is critical to the success of rehabilitation with dental prostheses and staining due to the increase in roughness and plaque accumulation is common. The rough surface caused by wearing the dentures and chemical degradation are also capable of affecting the brightness of artificial teeth and cause extrinsic staining, resulting in harm to the esthetic appearance of dental prostheses. In addition, due to reduced roughness, teeth made of resin composite with a high degree of cross-linking may harbor lower numbers of microorganisms [14].

Although there have been technological advancements in the search for better materials, artificial tooth wear is still common, causing loss of structure [12]. In this context, *in vitro* tests simulating the oral environment have been used to assess the clinical performance of artificial teeth and other materials [11, 23, 17]. Thermal cycling is a commonly used thermal fatigue method for simulating intra-oral aging of dental materials, such as artificial teeth [5]. In addition to the thermal effect, fractures or wear of artificial teeth may occur under continuous application of mechanical forces, resulting in loss of the dental prosthesis or ineffective repairs. Studies have found that different materials have shown a significant reduction in their mechanical properties after cyclic fatigue tests [9]. According to the authors' knowledge, there is no study in the literature that has evaluated the influence of thermal and mechanical cycles on the roughness and hardness of artificial teeth. The effect of the number of cycles, which indicates the period of use of the dental prosthesis, also needs to be evaluated. Thus, the aim of the present study was to investigate the effect of thermal and mechanical cycles on the hardness and roughness of the different brands of artificial teeth, since the oral environment is one in which restorative materials are subject to numerous changes.Furthermore, the effect of different cycles on these properties was also evaluated in order to predict the longevity of use of dental prostheses.

Material and Methods

Sample Fabrication

The trademarks, manufacturers and composition of artificial teeth that were used in this study are described in Table 1. The samples were fabricated according to Campanha et al. [6]. Posterior denture teeth (molars) were individually placed in PVC tubes (20 X 20 mm). Each tube was filled with melted wax (Wilson; Polidental Ind. e Com., Sao Paulo, Brazil) and invested in a denture flask (Jon 5.5; Jon Produtos Odontologicos, Sao Paulo, Brazil) in type III dental stone (Herodent; Vigodent, Bonsucesso, Brazil).The wax was boiled out, and the mold was packed with heat-polymerized acrylic resin (Vipi Wave).The resin denture teeth were placed in the center of the tubes.The acrylic resin was processed in accordance with the manufacturer's instructions. For the roughness analysis, artificial teeth were placed with occlusal surface face down (molars), so that the bottom flat surface of the tooth was parallel to the ring diameter, preserving the glaze of artificial teeth. For the hardness analysis, artificial teeth were placed in a resin mass into the rings, with occlusal surface facing upward (molars), parallel to the ring diameter.

Experimental groups

The sample size was calculated as 10 in each group (total=50 samples/brand, total=300 samples) using G* power 3.1.2 software (Effect size f= 0.25), (α err prob = 0.05), (Power (1-β err prob) = 0.95). For each material 50 samples were prepared, and the roughness and hardness readouts were taken at the following time intervals, according to the groups (n = 10):

Group 1: Measurements were taken after storage in distilled water at 37°C for 48 hours;

Group 2: Measurements were taken after mechanical cycling in the mechanical testing machine (Mechanical testing machine, manufactured by Material Test System, Eden Prairie, MN, USA; Model:MTS 810 Material Test System), calibrated in order to submit the specimens to 600.000 cycles, frequency of 15 Hz and an initial ramp rate of 10N/second, simulating 2.5 years of clinical use of the dental prosthesis [21].

Group 3: Measurements were taken after mechanical cycling in the mechanical testing machine (Mechanical testing machine, manufactured by Material Test System, Eden Prairie, MN, USA; Model: MTS 810 Material Test System), calibrated in order to submit the specimens to 1.200.000 cycles, frequency of 15 Hz and initial ramp rate of 10N/second simulating 5 years of clinical use of the dental prosthesis [21].

Table 1. Artificial teeth brands used in the study.

Material	Manufacturer	Composition
Vipi Dent Plus	Dental Vip Ltda, Pirassununga, SP, Brazil	PMMA, EDMA
Trilux	Dental Vip Ltda, Pirassununga, SP, Brazil	PMMA, EDMA (Double Cross Linked)
Biolux	Dental Vip Ltda, Pirassununga, SP, Brazil	PMMA, EDMA (Double Cross Linked)
Postaris	Ivoclar Vivadent Ltda, Sao Paulo, SP, Brazil	PMMA (Double Cross Linked)
Artiplus	Dentsply-DeguDent, Hanau, Germany	PMMA (Interpenetrating Polymer Network)
SR-Orthosit	Ivoclar Vivadent, Amherst, NY	UDMA and inorganic fillers

PMMA: Polymethylmethacrylate; EDMA: Ethylene dimethacrylate ; UDMA: Urethane dimethacrylate

Group 4: Measurements were taken after thermal cycling.For this group, thermal cycling consisted of 2.500 alternate baths in hot water (55ºC) and cold (5ºC) with dwell time of 30 seconds at each temperature, simulating 2.5 years of use of the dental prosthesis. The water volume was 20 liters and after every 500 cycles the water was exchanged.The equipment used for the thermal cycling was an MSCT-3 machine (São Carlos – SP) of about 2.500W and voltage 20V/60Hz.

Group 5: Measurements were taken after thermal cycling. For this group, the thermal cycles consisted of 5.000 alternate baths in hot water (55ºC) and cold (5ºC) with well time of 30 seconds at each temperature, simulating 5 years of use of the dental prosthesis. The water volume was 20 liters and after every 500 cycles the water was exchanged, using the same equipment as previously described.

The mechanical cycling tests (Groups 2 and 3) were performed with the specimens immersed in distilled water at 37 ± 0.5ºC.For this purpose, a receptacle with metal base and glass walls was created (17x13x9cm^3) and coupled to a heater (A 100 W Heater, fabricated by Master, Indústria de Equipamentos para Piscicultura, São Paulo, SP, Brazil), connected to a thermostat (Thermostat, manufactured by Hai Feng Feeds CO., Nangang Industrial Park, Nantou, Taiwan) with cell tolerance at a temperature of approximately 0.5ºC.

Surface roughness

After the cycling and storage procedures, specimens of each group were subjected to surface roughness readouts using a rugosimeter (Surftest SJ-401, Mitutoyo Sul Americana Ltda, Santo Amaro, SP) with a precision of 0.01µm. Five readouts were taken for each sample, at different locations in a predetermined and similar area for all specimens. The mean values of five readouts were obtained. The Ra parameter was chosen to ensure conditions of comparison with the results of other studies, reflecting the value of the arithmetic mean of all absolute distances of the roughness profile (Ra).

Hardness

A The hardness of all samples was obtained with the use of a Vickers diamond, which is considered a valuable tool to evaluate the hardness and viscoelastic properties of polymers, including artificial teeth [7, 18].The readouts were made in the Micromet 2100 device (Buehler, Lake Bluff, IL, USA), with 50 gf force for 15 seconds. The machine operator measured the lengths of the diagonals immediately after each advance, with a short period (10 s), thus avoiding the viscoelastic recovery of the diagonals. The measurements of the diagonals were converted into Knoop hardness readouts with a scale of one digit to the right of the decimal point.Eight indentations were performed on each sample, and the average value was calculated.

Statistical analysis

In this study, the roughness and hardness of 6 Brands of artificial teeth were evaluated, according to the 5 different experimental groups. For each group 10 specimens were prepared, totaling a sample of 300 specimens. The results were tabulated and subjected to the normality test to verify the distribution of the sample data.The hardness and roughness evaluations were made by three-way analysis of variance:three factors:material (artificial tooth brand), type of cycling (thermal or mechanical) and treatment group (simulating 2.5 or 5 years of dental prosthesis use), and a control group without cycling made of each material. This analysis was complemented by the Tukey multiple comparisons of means test. All comparisons were made at a 5% level of significance.

Results

Surface roughness

The means and standard deviations of roughness, according to the brands of artificial teeth and the treatments groups, with mechanical or thermal cycling are shown in Table 2: roughness after storage in distilled water (Group 1); roughness after mechanical cycling simulating 2.5 years of clinical use of dental prosthesis

Table 2: Mean (standard deviation) of roughness (Ra).

Average	Mechanical cycling			Thermo cycling		
	G1	G2	G3	G1	G4	G5
Trilux	0,42^{a}	3,28^{b}	5,31^{cd}	0,73^{a}	0,27^{a}	0,22^{a}
	(0,25)^{A}	(0,26)^{B}	(0,53)^{C}	(0,30)^{A}	(0,13)^{A}	(0,09)^{A}
Biolux	0,66^{ab}	4,68^{c}	4,44^{b}	0,71^{a}	0,90^{bc}	0,82^{abc}
	(0,19)^{A}	(0,77)^{B}	(0,36)^{B}	(0,23)^{A}	(0,56)^{A}	(0,17)^{A}
Vipi Dent	0,57^{ab}	4,64^{c}	5,09^{cd}	0,65^{a}	0,50^{ab}	0,47^{ab}
	(0,13)^{A}	(0,61)^{B}	(0,89)^{B}	(0,14)^{A}	(0,11)^{A}	(0,07)^{A}
Postaris	0,89^{abc}	4,96^{c}	5,41^{d}	0,97^{ab}	1,07^{bc}	0,91^{bc}
	(0,20)^{A}	(0,22)^{B}	(0,43)^{B}	(0,47)^{A}	(0,48)^{A}	(0,49)^{A}
Orthosit	1,13^{bc}	7,13^{d}	4,72^{bc}	1,15^{ab}	1,18^{c}	1,04^{bc}
	(0,10)^{A}	(0,34)^{C}	(0,34)^{B}	(0,25)^{A}	(0,08)^{A}	(0,14)^{A}
Artiplus	1,41^{c}	1,77^{a}	2,27^{a}	1,55^{b}	1,08^{bc}	1,10^{c}
	(0,08)^{A}	(0,09)^{AB}	(0,36)^{B}	(0,14)^{A}	(0,24)^{A}	(0,09)^{A}

Note: Averages accompanied by the same letter (lower case in vertical or upper case in horizontal) are not significantly different (p>0,05)

(Group 2); roughness after mechanical cycling simulating 5 years of clinical use of dental prosthesis (Group 3); roughness after thermal cycling simulating 2.5 years of clinical use of dental prosthesis (Group 4) and roughness after thermal cycling simulating 5 years clinical of use of dental prosthesis (Group 5).The analysis of variance indicated a significant effect of group in interaction between cycling and brands of teeth ($p<0{,}001$). After this, the Tukey test was performed to compare means; the results are summarized in Table 3.

It may be observed that there was no significant difference between G1, G4 and G5, in terms of mean roughness for any brand of artificial teeth.Groups G2 and G3 always presented higher meanand generally equivalent roughness, except for Trilux, for which G3 roughness values were higher than those for G2 (G3>G2).

Among the brands, thermal cycling always presented the lowest mean roughness, for all the groups. Whereas for mechanical cycling, for G2, the mean roughness found for the different brands was as follows: Artiplus < Trilux < (Biolux = Vipi Dent = Postaris) < Orthosit, while for G3 it was: Artiplus < Biolux ≤ Orthosit = Vipi dent = Trilux ≤ Postaris.

Hardness

Table 4 shows the means and standard deviations of hardness, according to the materials (brands of artificial teeth), type of cycling (mechanical or thermal) and treatment group; hardness readout after storage in distilled water (G1:control); hardness readout after cycling simulating 2.5 years of clinical use of dental prosthesis (G2 and G4) and hardness readout after cycling simulating 5 years of clinical use of dental prosthesis (G3 and G5).It may be noted that only there was a difference of only 3 hardness units between the lowest and highest mean values.

Analysis of variance showed a significant interaction between the three factors ($p=0.014$). Therefore, as there was no independence between the main effects, the Tukey test for comparing the means in pairs was applied, and the results are summarized in Table 5. It may be observed that there was no significant difference between the means of treatments with mechanical or thermal cycling, even when compared with the control, for Biolux, VipiDent and Artplus materials. For Trilux, the mean value of the control was lower than those of other treatments, which were all equivalent each other. For Orthosit, the mean value of the control and mechanical cycling in G2 were similar and higher than the means of the other treatments, which were all equivalent to each other. Among the materials, the mechanical cycling, in a similar manner to the thermal cycling when simulating 5 years of the use of the prosthesis (G3 and G5), no difference was shown between the means for any of the materials.The cycling simulating 2.5 years of clinical use of the dental prosthesis (G2 and G4) there were some differences, but at the most 2 hardness units. Compared with the

Table 3: Summary of analysis of variance on roughness (Ra).

Effect	Degrees of freedom	Quadratic Mean	F	p
Cycling	1	525,007	4265,13	$<0{,}001^{*}$
Tooth brand	5	11,404	92,64	$<0{,}001^{*}$
Group (Cycling x Brand)	24	27,487	223,31	$<0{,}001^{*}$
Cycling x brand	5	13,158	106,90	$<0{,}001^{*}$
Residue	324	0,123		

*5% significant.

Note: The results of multiple comparisons of means by Tukey test are summarized in Table1.

Table 4: Mean (standard deviation) hardness of according to the material (artificial tooth brand), type of cycling (mechanical and thermal) the simulation time of use of the prosthesis (2,5 years and 5 years).

Material	Control		Mechanical		Thermal
	G1	**G2**	**G3**	**G4**	**G5**
Trilux	22,30^{a}	23,94^{b}	23,35^{b}	23,53^{b}	23,24^{b}
	(0,85)^{A}	(1,19)^{A}	(0,38)^{A}	(0,49)^{AB}	(0,27)^{A}
Biolux	23,93^{a}	24,47^{a}	24,28a	23,56a	23,66a
	(0,66)B	(0,46)ABC	(0,40)^{A}	(0,27)^{AB}	(0,32)^{A}
VipiDent	23,46^{a}	23,66^{a}	23,63^{a}	23,30^{a}	23,59^{a}
	(0,36)^{B}	(0,24)^{A}	(0,37)^{A}	(0,17)^{A}	(0,39)^{A}
Postaris	23,47^{a}	25,09^{BC}	24,28^{ab}	25,46^{c}	23,62^{a}
	(0,40)^{B}	(0,90)^{BC}	(0,31)^{A}	(1,08)^{C}	(0,50)^{A}
Orthosit	25,30^{b}	25,39^{b}	24,24^{a}	24,26^{a}	23,70^{a}
	(1,08)^{C}	(0,53)^{C}	(0,28)^{A}	(0,63)^{B}	(0,26)^{A}
Artplus	24,16^{a}	24,33^{a}	23,96^{a}	24,00^{a}	24,16^{a}
	(0,40)^{B}	(0,33)^{AB}	(0,44)^{A}	(0,46)^{AB}	(0,40)^{A}

Note: Averages accompanied by the same letter (upper case in vertical or lower case in horizontal) are not significantly different ($p>0{,}05$) (Tukey test: $p>0{,}05$)

Table 5: Summary of analysis of variance on hardness with the type of cycling (mechanical or thermal), simulation time of use of the prosthesis (2, 5 or 5 years) and material (artificial tooth brand).

Source of Variation	Degrees of freedom	Quadratic mean	F	p
Cycling (C)	1	0,11	0,34	0,561
Time (T)	1	0,26	0,82	0,366
Material (M)	5	12,44	39,77	<0,001*
C x T	1	0,40	1,27	0,262
C x M	5	1,11	3,54	0,004*
T x M	5	3,10	9,90	<0,001*
C x T x M	5	0,91	2,91	0,014*
Residue	270	0,31		

*5% significant.

Note: The results of multiple comparisons of means by Tukey test are summarized in Table 1.

control, the lowest mean hardness was found for Trilux, and the highest mean for Orthosit, while the others showed intermediate values equivalent to each other.

Discussion

According to Itinoche et al. (2004), the presence of humidity and temperature variation in the oral cavity, mainly associated with mechanical forces generated during the masticatory cycle, provides conditions for the occurrence of degradation. Thermal cycling has been used to simulate the conditions of the oral medium with the purpose of verifying the performance of artificial teeth and other materials [11, 23, 17]. Whereas mechanical cycling may approximate the conditions in in vitro studies to the physiological conditions generated by the masticatory cycle. Therefore, the aim of this *in vitro* study was to evaluate the roughness and hardness of artificial teeth after different thermal and mechanical cycles.

Roughness

The results of the present study demonstrated that after thermal cycling, there were no alterations in the roughness of the materials tested, irrespective of the commercial brand and cycling time (simulating 2.5 and 5 years of dental prosthesis use). These results may also be explained considering the methodology used. Here the artificial teeth (molars) were embedded with the occlusal surface facing down, so that the flat bottom surface of the tooth faced upward, thereby preserving the superficial structure of the materials. Preservation of the superficial structure may have increased the resistance of the samples as regards roughness after thermal cycling. Whereas, the results of Oliveira et al. (2010) indicated that thermal cycling caused an increase in roughness in the majority of materials tested, without affecting hardness, while storage in water did not cause a significant increase in the properties evaluated. The studies of Silva Filho et al. (2006), showed that thermal cycling was capable of causing an increase in surface roughness of the materials tested. These differences may be explained considering the commercial brands evaluated, and considering the preservation of the surface layer of the samples, which was done in the present study.

With regard to mechanical cycling, the results showed that there was an increase in roughness after this process. Mechanical cycling may approximate the conditions in *in vitro* studies to the physiological conditions generated by the masticatory cycle. According to Fujii (1989), fatigue tests by means of mechanical cycling may contribute to the development and propagation of cracks starting from external or internal porosities present in the materials, and may therefore alter their roughness. The increase in roughness may favor biofilm accumulation, which has an influence on some properties, such as color alteration and may also favor the appearance of some diseases, such as oral candidosis. No studies on the effect of mechanical cycling on the roughness of artificial teeth were found in the literature to enable us to make direct comparisons.

The number of mechanical cycles was not a factor of influence on the roughness of the tested materials, except for the Trilux brand in G3, for which the roughness values were higher than they were in G2 (G3>G2). The increase in roughness may have occurred as a result of the increase in the number of mechanical cycles, which may have produced greater structural changes in the superficial layer of this material.

Among the brands, thermal cycling always presented lower mean roughness values for all the groups. Whereas, with mechanical cycling, the artificial teeth of the Artiplus brand, in Groups G2 and G3, presented the lowest roughness values. The differences in the roughness values after mechanical cycling may be explained considering the composition of each brand of artificial teeth. The quantity of cross-linking agents present in the different brands of artificial teeth may affect their properties. An increase in the quantity of cross-linking agents may improve the polymerization process of methyl methacrylate, resulting in a reduction in residual monomer, and consequently, improve the chemical and biologic properties [3, 8].

According to the manufacturer, the Artiplus brand of artificial teeth has a structure formed by an interpenetrant polymer network (external layer of polymer pearls in which the monomers migrate during processing of the tooth), which may improve the bond between the monomer and polymer, resulting in a lower quantity of residual monomer, and consequently, improve the mechanical properties of the material [27].

Hardness

In this study, the effect of thermal and mechanical cycling on the Knoop hardness of the different brands of artificial teeth was also evaluated. In addition, the effect of different numbers of cycles on this property was evaluated, in order to predict the correct time of use of dental prostheses.

The option was to use Knoop hardness, because the diagonal of the diamond-shaped figure measure to determine the hardness value (longest diagonal distance) remains free of dimensional changes, whereas the elastic recovery and alterations occur along the shortest diagonal distance [20, 28].

As regards the artificial teeth evaluated, the results pointed out that those of the Trilux brand showed the lowest hardness values. The differences in the roughness values may be explained considering the composition of each brand of artificial teeth. Different monomers may be used in the manufacture of artificial teeth, and may affect the hydrophilicity of the materials. Considering that hydrophilic materials exhibit greater water absorption than hydrophobic materials, the composition of the Trilux brand of artificial teeth (PMMA, EDMA and double cross-linking agents) may explain their hardness values being lower than those of the control group, since the teeth remained stored in distilled water at 37°C for 48 hours. Water may interfere in the mechanical properties of polymer-based materials, acting as a plasticizing agent, favoring softening by means of diffusion into the polymer chains (4), a condition that may cause a considerable reduction in the hardness of artificial teeth [28]. Similar results were found by Reis (2005), which showed difference in the hardness values of the Trilux brand after dynamic pH cycles. The Orthosit brand of teeth presented the highest hardness values. The teeth of the Orthosit brand have inorganic load particles in their composition. In addition, their polymeric structure is highly reticulated [26].

When the results of thermal and mechanical cycling were analyzed, it was observed that the artificial teeth of the Biolux, Vipi Dent and Artiplus brands were not influenced by either of the two treatments. These results could be indirectly compared with the results of Campanha et al., (2012), who observed that the hardness values were not affected by storage in water for 7 days. Similar results were also found by Reis (2005), which showed no difference in the hardness values of various brands of artificial teeth after dynamic pH cycles. The absence of effect on these resins may be attributed to the cross-links of the materials. The quantity of cross-links within the artificial teeth is higher than it is in denture base acrylic resins. The addition of cross-linking agents may improve the copolymerization of the methyl methacrylate, which results in a lower level of residual monomer. As a result, the properties of artificial teeth may be improved [3].

For the Trilux brand, thermal and mechanical cycling increased the hardness of the artificial teeth. These results are contrary to findings of the study of Assunção et al. (2010), who verified that thermal cycling reduced the hardness values of the artificial teeth evaluated. These differences may be explained by the methodology used in each study.

The increase in hardness of the Trilux brand may be explained by its composition associated with the increase in temperature during cycling. Trilux teeth are composed of PMMA, EDMA and double cross-linking (DCL), in addition to having a high molecular weight [19]. In theory, artificial teeth composed of DCL reduce the absorption of water into the polymer due to their inseparable chains and high resistance [28]. However, the increase in temperature may have induced a complementary polymerization reaction, having been facilitated by the cross-linking, and making the surface more rigid.

The results also showed that mechanical cycling reduced the hardness of the Orthosit brand of artificial teeth. According to Fujii (1989), fatigue tests by means of mechanical cycling may contribute to the development and propagation of cracks starting from external or internal porosities present in the materials, and may therefore alter their properties.

As regards the time of thermal or mechanical cycling, the hardness of all the brands of artificial teeth did not differ statistically in the simulations of 2.5 and 5 years of denture use, with the exception of the Postaris brand. Thus, we could suppose that the results obtained with regard to the type of cycling and composition of the materials are factors that may influence the choice of teeth, because the hardness remained stable during the period of time.

The results of the present study should be evaluated with caution. It is important to emphasize that the different types of artificial teeth are normally manufactured with various layers [16, 25] and this being so, in spite of the manufacturers affirming that there is no difference between the external surface and the internal portion, each layer of the artificial tooth may have different properties, such as hardness and monomer diffusion [29, 25]. Moreover, it may be postulated that thermal or mechanical cycling, as well as storage in water during the procedures may promote different effects on the surface hardness of artificial teeth, considering the manufacturing characteristics such as pressure and quantity of linking agents [28].

After a review of the pertinent literature, few studies were found with respect to the influence of the thermal or mechanical cycling process on the roughness and hardness of artificial teeth, thus making it difficult to perform direct comparisons with other studies. From the results of this study, new researches must be conducted with the aim of evaluating the influence of thermal and mechanical cycling on the properties of artificial teeth, making it possible to choose them with a view to durability during the fabrication of removable partial and complete dental prostheses. Furthermore, clinical researches are also recommended.

Conclusion

Within the limitations of this study, it could be concluded that:

1. In general, SR Orthosit artificial teeth presented the highest hardness value while the Trilux group exhibited the lowest hardness value;
2. The hardness of the Biolux, Vipi Dent and Artiplus brands of artificial teeth was not altered by thermal and mechanical cycles;
3. The thermal and mechanical cycles increased the hardness of the Trilux brand of artificial teeth;
4. The mechanical cycles decreased the hardness of SR Orthosit brand of artificial teeth;
5. As regards time, the hardness of the Postaris brand of teeth increased after 2.5 years of thermal and mechanical cycles;
6. The thermal cycles did not change the roughness of the artificial teeth tested;

7. The mechanical cycles increased the roughness of the artificial teeth tested;
8. After mechanical cycling, there were differences in the roughness values between the brands of artificial teeth tested.

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