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Effect of Different Solutions on Knoop Hardness of Indirect Composite Resins

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Abstract

Introduction: Indirect dental composites may have adequate clinical performance. However, the literature is scarce regarding indirect composite resins and these solutions should be considered to maintain their properties. The aim of the study was to evaluate the influence of beverages, mouthwashes and bleaching agents on the hardness of indirect composite resins.

Methods: Five different brands of indirect composite resins were evaluated: Adoro, Resilab, Cristobal, Sinfony and Epricord. Ten specimens of each brand were immersed in eleven different solutions: four mouthwashes (Listerine, Oral-B, Plax, Periogard), four beverages (coke soft drink, red wine, coffee, orange juice), three dental bleaching agents (16% peroxide of carbamide, 7.5% and 38% peroxide of hydrogen) and artificial saliva (control group). The Knoop hardness was measured before (baseline) and after 12, 24, 36 and 60 hours of immersion in mouthwashes; after 7, 14 and 21 days of immersion in beverages and after 7 and 14 days of immersion in dental bleaching agents. The results were analyzed using 3-way repeated measures ANOVA and Tukey's test ($p<0.05$).

Results: All resins presented significant decrease on hardness values after immersion process whereas this reduction was higher for Resilab and Sinfony. The latter exhibited the lowest initial values of hardness while Cristobol resin presented the highest hardness values. The mouthwashes promoted a significant decrease in the hardness of specimens.

Keywords: Hardness; Food; Dental materials; Hydrogen peroxide; Oral hygiene

Introduction

Indirect composite systems were introduced as an alternative to problems related to ceramic and direct composite restorations [1,2]. These indirect composites present high density of ceramic particles and alterations in their resin matrix [3]. Some of their properties such as the ability to strengthen a weakened tooth, great aesthetics, important physical properties and easy manipulation increase their popularity in dentistry market [4].

Indirect dental composites may have adequate clinical performance but it is extremely important to evaluate their physical and mechanical properties in high stress situations. An alteration of these properties might create micro-cracks in the restorations, loss of surface gloss, bacterial adhesion and color alteration leading the restorative treatment to failure [5,6]. The water absorption, the size and distribution of the inorganic particles as well as the consumption of common beverages may affect these properties, decreasing their hardness and facilitating the wear of their surfaces with the course of time [3].

There are studies that evaluated the water sorption in intraoral environment and the effect of common beverages and bleaching agents on the mechanical properties of direct composites [7-11]. However, the literature is scarce regarding indirect composite resins and these solutions should be considered to maintain their properties.

The aim of the study was to evaluate the effects of common beverages, mouthwashes and bleaching agents on the hardness of indirect composite resins. The hypothesis of this study was that the hardness of these composites is affected by the storage period and the solution.

Materials and Methods

Five different brands of indirect composite resins on B2 shade color were evaluated (Table 1). Sixty hundred specimens were fabricated. Ten specimens of each brand were immersed in eleven different solutions and artificial saliva (control group). The composition of the saliva was KCl (0.4 g L^{-1}), NaCl (0.4 g L^{-1}), $CaCl_{2}.{}_{2}H_2O$ (0.906 g L^{-1}), $NaH_2PO_{4}.{}_{2}H_2O$ (0.690 g L^{-1}), $Na_2S.{}_{9}H_2O$ (0.005 g L^{-1}), and urea (1 g L^{-1}) [12].

The specimens were fabricated by a metallic matrix (10 mm×5 mm×1.5 mm). The matrix consisted of an upper and a lower part. The latter was placed on a glass surface and filled with one of the test indirect composite resins. After, another glass plate was positioned over the resin layer to drain the excess of the material maintaining its surface smooth and homogeneous. The specimen was curried according to the manufacturer's instructions [13]. Subsequently, the upper part of the matrix was positioned over the lower part and it was filled with composite resin similarly to the first preparation stage. The matrix was carefully removed and the specimen was final curried according to the instructions of manufacturers.

After, specimens were sequentially polished with 240-, 400-, 800- and 1200-grit sandpaper (CarbiMet 2; Buehler, Lake Bluff, IL) in a semi-automatic polisher (Ecomet 300PRO, Buehler, Illinois, EUA). The procedure with the polishing machine was followed by the use of a polishing cloth (TexMet Polishing Cloth; Buehler) and a diamond paste (9-micron, MetaDi; Buehler). The thickness of each specimen was

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Comercial Brand	Manufacturer	Chemical Composition	Curing Procedure
Adoro	IvoclarVivadent Ltda., São Paulo, São Paulo, Brazil.	17 to 19% of dimethacrylate, 82to 83% of copolymers of silicon oxide and 1% of stabilizers, catalysts and pigments.	Initial curing procedure in Targis Quick pre-curing with halogen lamp (intensity of 600mW/cm^2).Then, the resin must be involved with glycerin gel and cured in the Lunamat 100 curing unit. Eight lamps emit a fluorescent light in mirrored environment for 25 minutes (10 minutes with light, 10 with heat at 1040ºC and 5 minutes with cooling of the curing unit. The potency hits 750W.
Resilab Master	Wilcos do Brasil, Industria e Comércio Ltda. Petrópolis, Rio de Janeiro, Brazil.	Small particles with mean size of 0.05mm, 53% of ceramic filler particles, BISGMA, BIGEMA, UDMA, TEGMA, Aluminum borosilicate, highly dispersible silicon acid, photo initiators, inhibitors and pigments.	Initial curing procedures for 4 minutes in EDG-Lux curing unit (400-500 mW/cm^2) with maximum temperature not exceeding 50ºC. Final curing for 8 minutes in EDG-Lux curing unit (400 -500 mW/cm^2).
Cristobal	DentisplyCeramco, Burlington, New Jersey, USA.	74% of inorganic particles of pyrogenic silica, barium glass and borosilicate.	Pre-curing in Mpa2000 curing unit for 90 seconds (200mW/cm^2) in a first stage and then for 75 seconds (800-1000 mW/cm^2) in a second stage. Final curing in Post Cure unit for 8 minutes at 80ºC.
Sinfony	3M ESPE, Campinas, São Paulo, Brazil.	48% of resin matrix (UDMA), 40% of strontium glass (macro particle of 0.6 µm), 5% pyrogenic silica (micro particle of 0.06 µm), 5% of glass ionomer cement particles, 1% silane and1% initiator.	Pre-curing for 15 seconds in Visio Alfa Light and Visio Beta VarioLigth curing unit associated with Visio Beta Vacuum pump (470 mW/cm^2). Final curing in two stages: 1 minute of light emission followed by 14 minutes of light emission in vaccum in Visio Beta.
Epricord	Kuraray Medical Inc, Tokyo, Japan.	53% ceramic filler content, 25% of multifunctional polymers, 22% of conventional resins photo initiators. The mean particle size is 0.6 µm.	Precuring for 30 seconds in Kota curing unit. Final curing for 180 seconds with halogen lamp (600 mW/cm^2) in Kota curing unit.

Table 1: Indirect composite resins evaluated.

Variation factors	*df*	SS	MS	F	*P*
Resin	4	92855.04	23213.76	1181.17	<0.001*
Common Beverage	4	185.66	46.41	2.36	0.054
Resin × common beverage	16	1352.73	84.55	4.30	<0.001*
Between samples	225	4421.95	19.65		
Period	3	13026.15	4342.05	2369.04	<0.001*
Period × resin	12	2002.01	166.83	91.03	<0.001*
Period × common beverage	12	136.65	11.39	6.21	<0.001*
Period × resin× common beverage	48	731.75	15.24	8.32	<0.001*
Intra samples	675	1237.16	1.83		

*P<.05 indicates statistically significant difference.

Table 2: Three-way repeated-measures analysis of variance (ANOVA) for common beverages.

measured with a digital caliper (500-171-20B, Mitutoyo, Tokyo, Japan) to obtain the proposed dimensions.

All the specimens were stored in distilled water at 37 ± 1°C (CIENLAB Equipamentos Cientificos Ltda, Campinas, Sao Paulo, Brazil) for 24 hours before hardness test [14-17].The Knoop hardness was determined using a hardness tester (HMV-2T; Shimadzu Corp., Kyoto, Japan) applying a 25g load for 10 seconds [11]. Then, the specimens were immersed in one of 11 test solutions: Listerine (Johnson & Johnson Ltda, São José dos Campos, São Paulo, Brazil), Oral B (Eurofarma Laboratórios Ltda, Itapevi, São Paulo, Brazil), Colgate Plax (Colgate-Palmolive Ldta, São Bernardo dos Campos, São Paulo, Brazil), Colgate PerioGard (Colgate-Palmolive Ldta, São Bernardo dos Campos, São Paulo, Brazil), coke soft drink (Coca-Cola, Cia de Bebidas Ipiranga, Indústria Brasileira de Bebida, Ribeirão Preto, São Paulo, Brazil), red wine (José Maria Da Fonseca Vinhos S.A, Azeitão, Portugal), coffee (Sara Lee Cafés do Brazil Ltda, Jundiaí, São Paulo, Brazil), orange juice (Coca-Cola, Cia de Bebidas Ipiranga, Indústria Brasileira de Bebida, Ribeirão Preto, São Paulo, Brazil) and three bleaching agents: 16% carbamide peroxide (FGM Produtos Odontológicos, Joinville, Santa Catarina, Brazil), 7.5% and 38% hydrogen peroxide (FGM Produtos Odontológicos, Joinville, Santa Catarina, Brazil). Ten specimens were immersed in artificial saliva (Farmácia de Manipulação Apothicário, Araçatuba, São Paulo, Brazil) as a control.

The specimens immersed in mouthwashes were stored in an incubator at 37 ± 1°C for 60 hours. The hardness test was performed after 12, 24, 36 and 60 hours. Sixty hours of immersion simulate the use of mouthwashes twice a day, during two minutes for five years [14]. The immersion process in the beverages was performed during 4 hours a day at 37 ± 1°C for 21 days. The specimens were stored in artificial saliva while they were not immersed in their respective beverages. The hardness test was determined after 7, 14 and 21 days of immersion. According to Guler et al., 24 hours of storage simulate the consumption of coffee for one month [15].

The specimens in bleaching agents were stored fortwo hours in 16% carbamide peroxide [16], two hours in 7.5% hydrogen n peroxide and for 40 minutes in 38% hydrogen peroxide per day during 14 days. The immersion process in bleaching agents was conducted at 37 ± 1°C for 14 days. Then, the specimens were stored in artificial saliva [16]. The hardness test was performed after 7 and 14 days of immersion.

After each period of immersion in the mouthwashes, beverages and bleaching agents, the Knoop hardness test was repeated. The solutions were replaced after each period of immersion. The authors verified visible color alterations after the immersion in all the tested solutions although the color change was not the purpose of this study. The specimens immersed in the mouthwashes became more greenish, the specimens immersed in the beverages became more darkened and the specimens immersed in the bleaching agents became brighter.

A three-way repeated-measures analysis of variance (ANOVA) was performed to identify significant differences among the resins, the solutions used, and immersion period. The Tukey-Kramer HSD test was used for post-hoc analysis. All data were analyzed at a significance level of 0.05.

Results

There were significant differences among the immersion period, resins and the solutions used (mouthwashes, beverages and bleaching agents). However, only the mouthwashes affected significantly the hardness of indirect composite resins regardless the resins and immersion period comparing them with other solutions (Tables 2-4).

The Sinfony resin exhibited the lowest initial values of hardness while Cristobol resin presented the highest initial values of hardness (Tables 5-7).

All resins presented significant decrease on hardness values along the immersion in the different solutions whereas this reduction was higher for Resilab and Sinfony (Tables 4, 5 and 7).

Discussion

The hypothesis of the study was accepted because among the evaluated factors, only the mouthwashes and immersion period affected significantly the hardness of the specimens.

The beverages and the bleaching agents may not have affected the hardness because of the polish and finishing processes that removed the instable layer of the resin enhancing the resistance to chemical solutions [17]. However, this fact did not occur with mouthwashes whereas these solutions affected the hardness of the resins. The decrease of hardness may be attributed to the intention of simulating two years of patient's hygiene habits, leading to a continuous storage of the specimens. Thus, the specimens were in direct contact with the alcohol content of the mouthwashes which might soften the resins affecting the adhesion of their filler particles to the matrix resins and leading the surface more susceptible to degradation [7,18]. Festuccia et al. affirmed that even with no alcoholic content, the alcohol-free mouthwashes have phosphoric acid in its composition which can damage the resin affecting the longevity of composite restorations [18].

Resin	Common beverages	Period			
		Inital	After 7 days	After 14 days	After 21 days
Adoro	Saliva	43.00 (3.13) Aa	42.13 (4.08) Aa	39.24 (4.75) Aa	38.70 (4.49) Aa
	Coke	42.73 (2.57) Aa	39.33 (1.24) Aab	36.41 (1.92) ABCb	35.87 (2.17) ABCb
	Wine	42.62 (2.40) Aa	39.97 (1.92) Aa	31.79 (1.11) BCb	31.38 (1.67) BCb
	Coffe	43.57 (1.93) Aa	40.28 (2.10) Aa	33.88 (1.20) Bb	33.16 (1.19) Bb
	Juice	42.59 (2.22) Aa	40.84 (3.20) Aa	38.43 (1.31) ABa	37.85 (1.11) ABa
Resilab	Saliva	42.08 (3.57) Aa	28.94 (3.50) Ab	28.45 (4.48) ABb	24.82 (3.30) Ab
	Coke	42.25 (2.25) Aa	31.17 (3.71) ABb	28.24 (4.92) Abc	25.61 (4.34) Ac
	Wine	42.28 (2.72) Aa	29.61 (3.97) Ab	29.97 (3.75) ABb	28.38 (3.51) Ab
	Coffe	42.66 (2.69) Aa	29.24 (3.44) Ab	28.43 (2.20) ABb	26.16 (2.96) Ab
	Juice	44.58 (3.56) Aa	34.89 (5.63) Bb	33.12 (6.13) Bbc	28.54 (3.47) Ac
Cristobol	Saliva	48.82 (1.97) Aa	46.07 (1.38) Aab	43.83 (1.41) Ab	41.56 (1.62) Ab
	Coke	48.36 (1.08) Aa	42.81 (0.60) ABb	39.43 (1.05) ABb	38.28 (0.60) Ab
	Wine	47.82 (1.04) Aa	44.37 (1.94) Aab	42.95 (2.16) Ab	42.24 (2.60) Ab
	Coffe	47.92 (0.38) Aa	39.19 (0.37) Bb	37.80 (0.55) Bb	39.16 (1.84) Ab
	Juice	48.26 (0.48) Aa	43.42 (1.29) ABb	40.32 (1.34) ABb	39.42 (1.97) Ab
Sinfony	Saliva	21.15 (3.79) Aa	13.65 (3.98) Ab	12.35 (2.86) Ab	11.37 (3.67) Ab
	Coke	20.16 (1.73) Aa	15.28 (2.08) Ab	13.83 (2.33) Ab	13.72 (2.54) Ab
	Wine	20.76 (1.16) Aa	14.87 (2.36) Ab	13.36 (2.65) Ab	12.91 (2.66) Ab
	Coffe	19.99 (1.49) Aa	13.56 (1.53) Ab	13.50 (1.51) Ab	12.05 (1.56) Ab
	Juice	20.05 (0.91) Aa	13.62 (1.18) Ab	12.33 (1.30) Ab	11.11 (2.48) Ab
Epricord	Saliva	38.96 (0.82) Aa	34.95 (0.82) Aab	34.71 (1.60) Aab	33.10 (0.79) ABb
	Coke	40.24 (1.38) Aa	34.16 (2.15) Ab	32.12 (2.84) Ab	31.03 (2.66) ABb
	Wine	39.38 (0.95) Aa	34.82 (2.25) Aab	34.02 (2.18) Ab	35.85 (1.80) Aab
	Coffe	40.70 (0.73) Aa	35.36 (1.20) Ab	34.71 (1.27) Ab	33.97 (0.94) ABb
	Juice	39.62 (0.29) Aa	34.19 (1.91) Ab	32.07 (1.54) Ab	30.61 (1.80) Bb

Means followed by the same uppercase letter in the column (comparison of each resin brand) and the same lowercase letter in the line does not differ to 5% level of significance ($P<.05$) in Tukey's test.

Table 3: Mean results (Standard Deviation) of Knoop hardness of indirect composite resins for common beverages.

Variation factors	*df*	SS	MS	F	*P*
Resin	4	120522.51	30130.63	782.58	<0,001*
Mouthwash	4	2918.14	729.53	18.95	<0,001*
Resin x mouthwash	16	1070.29	66.89	1.74	0.041*
Between samples	225	8662.83	38.50		
Period	4	19070.18	4767.55	1932.05	<0,001*
Period x resin	16	707.45	44.22	17.92	<0,001*
Period x mouthwash	16	854.01	53.38	21.63	<0.001*
Period x resin x mouthwash	64	572.12	8.94	3.62	<0.001*
Intra samples	900	2220.85	2.47		

*P<.05 indicates statistically significant difference.

Table 4: Three-way repeated-measures analysis of variance (ANOVA) for mouthwashes.

Resin	Solution	Period				
		Inital	12 hours	24 hours	36 hours	60 hours
Adoro	Saliva	43.00 (3.13) Aa	40.06 (4.00) Aab	37.36 (5.62) Aab	37.13 (4.62) Aab	35.82 (4.60) Ab
	Listerine	43.20 (2.88) Aa	34.80 (4.34) Ab	33.39 (4.30) Ab	32.02 (2.56) Ab	29.76 (2.30) Ab
	Oral-B	42.62 (0.91) Aa	39.03 (4.38) Aab	36.04 (4.60) Ab	35.06 (5.07) Ab	33.65 (5.76) Ab
	Plax	42.87 (1.54) Aa	36.63 (3.34) Ab	33.71 (2.99) Abc	31.10 (2.42) Abc	30.14 (1.72) Ac
	Periogard	42.71 (1.31) Aa	37.61 (3.73) Aab	34.88 (2.92) Ab	34.25 (2.73) Ab	31.63 (3.28) Ab
Resilab	Saliva	42.08 (3.57) Aa	36.60 (5.28) Aab	35.87 (5.03) Ab	33.82 (4.23) Ab	31.08 (3.63) Ab
	Listerine	42.54 (3.88) Aa	31.63 (5.36) Ab	30.53 (4.41) Ab	28.06 (3.77) Abc	24.33 (4.31) Bc
	Oral-B	41.97 (2.25) Aa	34.04 (3.20) Ab	33.05 (3.45) Ab	31.39 (2.95) Ab	28.43 (4.20) ABb
	Plax	43.76 (3.84) Aa	35.07 (4.75) Ab	33.90 (4.59) Ab	32.33 (3.80) Ab	30.00 (3.65) ABb
	Periogard	42.30 (3.45) Aa	33.29 (3.52) Ab	32.52 (3.34) Ab	31.11 (3.09) Ab	30.71 (3.34) Ab
Cristobol	Saliva	48.82 (1.97) Aa	47.79 (2.21) Aa	45.89 (1.56) Aab	43.06 (1.87) Aab	40.31 (1.01) Ab
	Listerine	48.16 (2.49) Aa	41.98 (1.38) Ab	38.34 (1.32) Bbc	36.79 (1.17) Bbc	32.94 (0.91) Bc
	Oral-B	48.72 (2.29) Aab	47.00 (2.39) Aa	41.22 (1.77) ABac	39.12 (1.19) Abc	36.35 (1.12) Abc
	Plax	48.08 (0.92) Aa	46.93 (0.54) Aab	45.19 (1.86) Aab	41.33 (2.96) ABb	38.95 (2.78)ABbc
	Periogard	49.18 (3.18) Aa	44.38 (2.11) Aab	42.83 (1.93) ABb	39.89 (3.10) ABb	37.15 (3.40)ABbc
Sinfony	Saliva	21.15 (3.79) Aa	19.66 (6.45) Aab	17.73 (5.58) Aab	14.72 (5.10) Ab	12.95 (4.74) Abc
	Listerine	19.97 (1.46) Aa	7.51 (1.87) BCb	6.71 (1.23) BCb	6.83 (1.42) Bb	5.37 (1.06) Bb
	Oral-B	20.12 (0.75) Aa	14.76 (0.90) ACab	14.02 (1.28) ACab	12.40 (0.88) ABb	11.37 (0.69) ABb
	Plax	19.86 (2.14) Aa	13.73 (4.86) ACb	13.51 (4.11) ACb	12.55 (3.89) ABb	11.25 (3.04) ABb
	Periogard	20.52 (1.22) Aa	11.29 (1.57) Cb	10.56 (1.22) Cb	10.39 (0.91) ABb	9.62 (0.48) ABb
Epricord	Saliva	38.96 (0.82) Aa	34.95 (1.62) Aa	34.10 (3.10) Aa	33.61 (2.53) Aa	33.25 (2.38) Aa
	Listerine	40.88 (1.85) Aa	33.03 (3.02) Ab	31.43 (2.50) Ab	30.46 (3.62) Ab	28.55 (2.13) Ab
	Oral-B	40.17 (1.83) Aa	33.65 (1.49) Ab	30.82 (1.99) Abc	29.46 (1.84) Abc	27.27 (1.76) Ac
	Plax	40.88 (1.89) Aa	33.45 (2.74) Ab	30.32 (2.75) Ab	28.80 (2.67) Ab	27.84 (3.00) Ab
	Periogard	40.84 (1.63) Aa	35.07 (3.44) Aab	32.35 (2.31) Ab	30.74 (2.87) Ab	29.75 (4.22) Ab

Means followed by the same uppercase letter in the column (comparison of each resin brand) and the same lowercase letter in the line does not differ to 5% level of significance (P<.05) in Tukey's test.

Table 5: Mean results (Standard Deviation) of Knoop hardness of indirect composite resins for mouthwashes

Variation factors	*df*	SS	MS	F	*P*
Resin	4	63207.62	15801.90	927.98	<0.001*
Bleaching agent	3	11.59	3.86	0.23	0.878
Resin × bleaching agent	12	323.24	26.94	1.58	0.100
Between samples	180	3065.10	17.03		
Period	2	6830.67	3415.33	1390.49	<0.001*
Period × resin	8	1231.81	153.98	62.69	<0.001*
Period × bleaching agent	6	31.47	5.24	2.14	0.048*
Period × resin × bleaching agent	24	288.73	12.03	4.90	<0.001*
Intra samples	360	884.23	2.46		

**P*<.05 indicates statistically significant difference.

Table 6: Three-way repeated-measures analysis of variance (ANOVA) for bleaching agents.

The objective of a secondary polymerization is to maximize the degree of conversion of composites in order to improve mechanical and physical properties, durability, solvent resistance and biocompatibility [19]. The presence of non-polymerized monomer in the matrix affects the properties of composite materials and may induce surface degradation and discoloration [20]. Some studies showed improvement of some mechanical properties such as fracture toughness, flexural strength and hardness of composites when increasing the degree of conversion due to additional polymerization [10,19,21]. However, an improvement in the degree of conversion does not necessarily result in better mechanical properties because these are also related to other factors such as resin composition, filler content, particle size and distribution as was said in this study.

Due the difference in composition and curing method recommended by each manufacturer of indirect resins the degree of conversion can be affected. This can also explain the different values for initial hardness of the materials. Based on the investigation above, the characteristics of the material should be known to obtain a great durability of indirect composite restorations. The size and quantity of filler particles have a direct influence on the hardness of resins [22]. The increasing of the inorganic content on these composites prevents the plastic deformation in the organic matrix because it enhances the adhesion of filler particles to it, shortens the polymeric chains [23] and decreases water absorption [11] as observed in the current study since Cristobol has 74% of inorganic content [9]. Besides, composites with smaller particles are more resistant to wear because they are more homogenous and have less salient particles in their surface [22].

However, not only the filler particles have effect on the mechanical properties of indirect composite resins. According to Sideridou et al., the composition of the resins can also influence their mechanical characteristics [24]. The Sinfony resin has basically UDMA in its composition. This chemical compound increases the susceptibility of the resins to beverages solvents since it has molecules of CO and NH_2 which are easily broken by water causing greater sorption of it.

Resin	Bleaching	Period		
		Initial	After 7 days	After 14 days
Adoro	Saliva	43.00 (3.13) Aa	42.13 (4.08) Aa	39.24 (4.75) Aa
	Carbamide	43,21 (2.19) Aa	40.29 (1.92) Aa	39.71 (2.07) Aa
	7.5% Hydrogen	43.36 (2.81) Aa	39.75 (4.26) Aab	38.36 (4.32) Ab
	38% Hydrogen	44.39 (2.00) Aa	40.49 (3.11) Aab	36.41 (3.08) Ab
Resilab	Saliva	42.08 (3.57) Aa	28.94 (3.50) Ab	28.45 (4.48) Ab
	Carbamide	42.84 (1.62) Aa	34.64 (3.79) Bb	28.92 (3.26) Ac
	7.5% Hydrogen	44.88 (2.41) Aa	35.14 (4.80) Bb	28.46 (1.95) Ac
	38% Hydrogen	42.91 (3.26) Aa	34.86 (3.97) Bb	31.39 (3.00) Ab
Cristobol	Saliva	48.82 (1.97) Aa	46.07 (1.38) Aab	43.83 (1.41) Ab
	Carbamide	48.04 (0.84) Aa	42.54 (1.79) Ab	40.73 (1.70) Ab
	7.5% Hydrogen	49.37 (3.94) Aa	44.55 (2.11) Aab	41.67 (2.46) Ab
	38% Hydrogen	50.22 (2.98) Aa	43.41 (2.21) Ab	42.58 (1.50) Ab
Sinfony	Saliva	21.15 (3.79) Aa	13.65 (3.98) Ab	12.35 (2.86) Ab
	Carbamide	20.41 (1.91) Aa	12.63 (2.90) Ab	12.47 (2.64) Ab
	7.5% Hydrogen	20.97 (1.71) Aa	12.83 (1.31) Ab	12.32 (0.99) Ab
	38% Hydrogen	20.67 (2.38) Aa	12.70 (1.65) Ab	11.34 (1.69) Ab
Epricord	Saliva	38.96 (0.82) Aa	34.71 (1.60) Aab	33.95 (0.64) Ab
	Carbamide	39.66 (1.44) Aa	35.10 (2.58) Aa	34.81 (2.34) Aa
	7.5% Hydrogen	39.46 (0.85) Aa	34.42 (1.49) Ab	34.38 (1.13) Ab
	38% Hydrogen	39.96 (2.43) Aa	35.29 (2.45) Aab	34.66 (1.91) Ab

Means followed by the same uppercase letter in the column (comparison of each resin brand) and the same lowercase letter in the line does not differ to 5% level of significance (P<.05) in Tukey's test.

Table 7: Mean results(Standard Deviation) of Knoop hardness of indirect composite resins for bleaching.

As Bagheri et al. affirmed, the water has the ability to penetrate the polymeric chains separating the filler particles of the matrix resin [25]. According to this statement, it can be observed that Resilab showed lower hardness results. This fact may be attributed to the hydrophilic monomers (TEGDMA) content in its composition which promotes great water absorption what may affect the resin hardness [26]. This uptake produces leaching of the ceramic filler particles of the resin matrix. Probably, it happens due to the breakdown of the silane bond between the resin and the filler particles [26]. This factor may have promoted the hardness reduction of Resilab and Sinfony since both have lower inorganic content, hydrophilic chemical compounds in the resin matrix and bigger particles than the others test indirect composite resins which facilitate the water incorporation into the polymeric chains and the leaching of filler particles with the course of time.

Even with all the considerations present in literature about the factors that can affect the mechanical properties of composite resins, the laboratory simulations in which the specimens are immersed in different storage medias have the bias of not including the effect of biofilm and real saliva [27]. Peutzfeldt et al. affirmed that the influence of mouthwashes can be modified clinically by many factors, for example, real saliva may neutralize the pH of these solutions reducing the softening of the resin and promoting a protective effect on its surface [19]. In the current study, the results are consistent with other studies that evaluated the hardness of indirect composite resins, demonstrating despite the bias of the methodology, the results have clinical correspondence to the resins performance [11,28].

So, it can be verified that there were alterations in the hardness of the specimens after immersion in the different solutions. Cristobol and Sinfony presented the greater and lower hardness results, respectively. Furthermore, Resilab and Sinfony had the greater decreasing of hardness, confirming that the longevity of the indirect composite resins is directly linked with their composition. Only the mouthwashes significantly reduce the hardness of the specimens.

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