THE JOURNAL OF PROSTHETIC DENTISTRY

RESEARCH AND EDUCATION

Determining acceptable limits for water sorption and solubility of interim denture resilient liners

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ABSTRACT

Statement of problem. Specifications for determining acceptable limits of water sorption (WS) and solubility for interim denture resilient liners are lacking.

Purpose. The purpose of this in vitro study was to evaluate the WS and solubility of interim resilient materials throughout their lifespans.

Material and methods. Specimens (n=10) of 7 tissue conditioners, Coe-Comfort (CC), Softone (ST), Rite-Line (RL), Dura Conditioner (DC), Hydrocast (HC), Dentusoft (DS), and Visco-gel (VG) and 2 interim resilient liners, Trusoft (TS) and Coe-Soft (CS), were submitted to desorption until weight stabilization. Next, they were immersed in distilled water at 37°C for 3, 5, 7, or 14 days and then weighed, dried, and reweighed. Data (%) were analyzed using 2-way ANOVA and the Tukey honestly significant difference (HSD) test (α=.05).

Results. VG demonstrated the highest WS (12.06 ±0.93%-16.62 ±0.87%) and solubility (20.30 ±4.26%-23.59 ±2.24%; P<.05) percentages. Low WS values were presented by CC (2.23 ±0.53%-2.99 ±0.49%; P<.05). The WS showed no significant changes for CC, CS, and TS over 14 days (P>.05). SL presented intermediate solubility values (4.09 ±1.60%-8.80 ±1.15%), and the other materials showed values lower than 3.35 ±0.70%. CC, DC, DS, HC, RL, TS, and CS showed no changes in solubility throughout the 14-day trial.

Conclusions. Over the lifespan of a tissue conditioner (7 days), CC, RL, DC, HC, DS, CS, and TS presented suitable in vitro performance. Among the tested materials, CC, CS, and TS were considered best suited for denture relining for up to 14 days. (J Prosthet Dent 2019;121:311-6)

Tissue conditioners and interim resilient liners are soft materials widely used for the intaglio surface of a removable complete denture to allow time for tissue healing.[1,2] Therefore, these materials are often used to protect surgical wounds and condition the supporting mucosa damaged by ill-fitting dentures, providing comfort for the patient.[3] According to the Glossary of Prosthodontic Terms,[1] interim resilient liner resins are used in functional removable relining procedures to evaluate denture function and patient acceptance before laboratory reline processing. Liner resins may also be used in creating functional impressions for complete dentures[4-6] and stabilization of record plates during the recording of maxillomandibular relationships. These materials may also be indicated as supporting treatment for denture stomatitis, especially when modified by the addition of medicaments.[3,7]

Ideally, resilient materials should promote the distribution of functional stresses on the alveolar ridge, absorbing energy over the mucosa during mastication.[8,9] However, these materials may undergo permanent deformation and cause denture instability,[10] which may

Supported by São Paulo Research Foundation grants 2012/11074-2 and 2015/03536-4, Tutorial Education Program, and National Council for the Improvement of Higher Education.
Presented at 33rd Annual Meeting of Brazilian Division of the International Association for Dental Research, Campinas, São Paulo, Brazil, September, 2016. Received first place award (Myaki Issao, Area 6, Prosthesis).
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Clinical Implications

Clinicians should consider the acceptable limits of water sorption and the solubility of interim denture resilient liners, because these physical properties are related to dimensional stability, degradation, and patient comfort.

vary according to their properties, especially water sorption (WS) and solubility.[11,12] In an ideal situation, the resilient liner should contain insoluble components and display low WS.[13,14] Nevertheless, during their lifespans, these products are exposed to saliva, foods, water, and cleansers,[14-16] which may cause WS and loss of plasticizers and other soluble components.[11,17]

WS in acrylic resin causes a slight expansion of the polymerized bulk and simultaneously interferes with the interlocking of the polymeric chain, acting as a plasticizer, which alters the physical characteristics of the material.[18] In acrylic resin-based resilient materials, especially interim materials whose resilience is provided by the high concentration of plasticizers and solvents in the matrix,[19] the loss of these components to the aqueous environment is much higher than the plasticizer effect of water.[20] Consequently, the longevity of these polymers is impaired due to loss of their resilience[2] and ability of impact absorption, which reduce the comfort they provide.[21] Likewise, the lifespan of these materials is limited to between 3 and 5 days for tissue conditioners and nearly 14 days for interim resilient liners.[22-25]

Different from denture base acrylic resins, clinically acceptable values of WS and solubility have not been determined by international specifications for interim resilient denture materials. Also, comparison of the few investigations available[5,9,26-30] is impaired by the lack of standardized methodology to evaluate the properties and by the varied dimensions of specimens, which are also not specified in a worldwide standard.

The International Organization for Standardization (ISO) specification 10139-2 for long-term resilient denture liners recommends calculation of WS and solubility in units of $\mu g/mm^3$, according to specimen volume.[31] This method was adopted in research of interim resilient denture liners modified by antifungal agents.[28] Some studies[9,29,30] adopted specification 12 of the American Dental Association (ADA)[32] for denture base acrylic resin to determine these properties for interim resilient liners, using the surface area of specimens to achieve values in mg/cm^2. According to ISO[31] and ADA specifications,[32] the volume and surface area used in the formulas are identical for all specimens because they are calculated according to their dimension (50×0.5 mm). Other studies of interim resilient liners[5,33] used the method suggested by Kazanji and Watkinson,[14] determining the WS and solubility of long-term resilient liners in percentages, which seems more useful because the values are achieved according to the individual dry and humid weights of specimens. Concerning the dimensions of specimens for analysis of WS and solubility of interim resilient materials, some studies used disk-shaped specimens (50×0.5 mm), meeting both ADA specification 12 for denture base acrylic resin and ISO standard 10139-2 for long-term resilient liners.[9,26,28,29] However, other investigations of the same properties of interim resilient materials adopted various dimensions for specimens which are not specified in international guidelines.[5,27,30]

Considering the differences between methodologies in previous studies and the lack of specifications for the acceptable limits for WS and solubility of interim resilient denture materials, the purpose of this study was to evaluate these properties in a standardized manner for different commercially available tissue conditioners and interim resilient liners throughout their lifespans. The research hypothesis was that WS and solubility would vary according to the material type and evaluation time.

Table 1. Interim resilient materials tested

Type/Material	Acronym	Batch No.		Manufacturer
		Powder	Liquid	
Tissue conditioners				
Coe-Comfort	CC	1209061	1209071	GC Europe N.V.
Dura conditioner	DC	090313	091913	Reliance Dental Mfg LLC
Dentusoft	DS	10393	10398	Densell Dental Technology
Visco-gel	VG	130725	131200004	Dentsply Sirona
Softone	ST	1108-346	1108-346	Bosworth Co
Hydro-Cast	HC	1200211109	0250210972	Kay-See Dental Mfg Co
Rite-Line	RL	102346	102327	Rite-Dent Mfg Corp
Short-term resilient liners				
Trusoft	TS	1503-140	1503-140	Bosworth Co
Coe-Soft	CS	1210182	1210191	GC America Inc

MATERIAL AND METHODS

The interim resilient materials selected for this study are presented in Table 1. For individual specimen fabrication, the materials were proportioned and mixed according to the manufacturers' instructions. The material powder was added to the liquid, and the resulting mixture was poured into a round stainless steel mold, which was pressed between 2 glass plates until final plasticization as determined by the manufacturer. Then, each specimen was removed from the mold, and the excess material was removed by using a scalpel; thus, 10 disk-shaped specimens (50 mm in diameter and 0.5 mm thick)[9,26,28,29] were fabricated for each material (n=10) in each time period.[23,34]

Table 2. Summary of 2-way ANOVA of WS

Source	*df*	Type III SS	MS	F	*P*
Material	8	3292.14	411.52	242.91	<.001
Time	3	579.93	193.31	114.11	<.001
Material×Time	24	211.16	8.80	5.19	<.001
Error	324	548.88	1.69		

MS, mean square; SS, sum of squares; WS, water sorption.

Initially, specimens were submitted to desorption in a vacuum desiccator at 37°C ±0.5°C and weighed daily using a digital analytic balance (UMark 210 A; BEL Engineering srl), until a constant weight was obtained (W1). Weights were considered stable when the differences among the means of 3 weighed specimens were smaller than 0.0001 g in 24 hours.[35] Then, the specimens were immersed in 20 mL[28] of water at 37°C ±0.5°C[35] for 3, 5, 7, or 14 days.[23,34] After immersion, excess water was carefully removed from the specimens, using absorbent paper, and they were allowed to air dry for 15 seconds and weighed again 1 minute after removal from the water (W2).[26,30] Finally, all specimens were again subjected to desorption as previously described and weighed again (W3). Percentages of WS and solubility were calculated according to the individual dry and humid weights of each specimen by using the following equations[14]: WS (%) = (W2 − W3) × 100/W1, and Solubility (%) + (W1 − W3) × 100/W1, where W1 is the weight (μg) after the first desorption, W2 is the weight after water immersion, and W3 is the weight after the second desorption process. Because determination of WS and solubility prevented reuse of the specimen, for each interim resilient material tested, Coe-Comfort (CC), Dura Conditioner (DC), Dentusoft (DS), Visco-gel (VG), Softone (ST); Hydrocast (HC), Rite-Line (RL), Trusoft (TS), and Coe-Soft (CS), 10 specimens were fabricated for each evaluation time (3, 5, 7, and 14 days).[5,36] Therefore, a total of 360 specimens were produced. WS and mean solubility percentages were statistically analyzed by 2-way ANOVA ("material" and "time"), followed by the Tukey honestly significant difference (HSD) post hoc test (α=.05). Statistical tests were performed using statistical software (SigmaPlot for Windows [Microsoft] v12.0; Systat Software Inc).

RESULTS

For the number of specimens (n=10) used for WS, the study was adequately powered for both the "material" and "time" factors (100%; α=.05). ANOVA detected statistical significance for the factors "material" (P<.001) and "time" (P<.001) and the interaction between them (P<.001) (Table 2). Results of WS (%) are described in Table 3.

Considering each material in the different evaluation times, tissue conditioner CC and interim resilient liners CS and TS did not present significant alterations in WS over the 14 days of water immersion (P>.05). A progressive increase was seen in WS values for DC and RL from 3 to 7 days and from 7 to 14 days of immersion (P<.05), and WS at 5 days did not differ significantly from that after 3 or 7 days for these materials (P>.05). The tissue conditioners DS, ST, HC, and VG presented statistically significant changes in WS only at 14 days (P<.05) (Table 3).

Table 3. Mean ±standard deviation percent values of water sorption for the interim resilient materials in the evaluation periods

Material	3 days	5 days	7 days	14 days
Coe-Comfort	2.23 ±0.53^{Ad}	2.43 ±0.27^{Ad}	2.93 ±0.50^{Ad}	2.99 ±0.49^{Ae}
Dura Conditioner	5.51 ±1.18^{Cbc}	7.48 ±2.10^{BCb}	8.72 ±1.53^{Bb}	11.14 ±1.85^{Ab}
Dentusoft	6.79 ±1.01^{Bb}	7.65 ±1.19^{Bb}	6.96 ±3.14^{Bbc}	10.02 ±1.14^{Ab}
Visco-gel	12.06 ±0.93^{Ba}	13.04 ±1.18^{Ba}	14.29 ±1.01^{Ba}	16.62 ±0.87^{Aa}
Softone	4.57 ±0.51^{Bbc}	2.90 ±1.08^{Bd}	4.04 ±1.32^{Bd}	7.22 ±2.38^{Ad}
Hydro-Cast	5.69 ±0.50^{Bbc}	6.00 ±0.83^{Bbc}	7.23 ±1.04^{Bb}	9.88 ±1.34^{Ab}
Rite-Line	4.75 ±0.62^{Cbc}	6.41 ±0.67^{BCb}	7.21 ±0.89^{Bbc}	9.54 ±1.20^{Abc}
Trusoft	3.99 ±0.31^{Acd}	3.71 ±1.65^{Acd}	4.99 ±0.64^{Acd}	5.76 ±1.25^{Ad}
Coe-Soft	6.54 ±1.69^{Ab}	6.95 ±1.19^{Ab}	6.50 ±2.09^{Abc}	7.35 ±1.34^{Acd}

WS, water sorption. Different superscript letters (uppercase: within row; lowercase: within column) significantly different (P<.05).

Comparisons among materials in the evaluation periods revealed that VG had the highest mean percentages of WS in all times (P<.05). At 3 days, the lowest WS value was observed for CC (P<.05), which was not statistically different from that of TS (P>.05). No significant differences in WS values were noted among tissue conditioners TS, HC, DC, RL, and ST (P>.05). WS values for DS and CS were only higher than those of materials TS and CC (P<.05) and were lower than those of VG (P<.05). At 5 and 7 days, CC showed the lowest WS values (P<.05), which were not statistically different from the values of ST and TS (P>.05). At 5 days, no significant differences (P>.05) were observed among the WS values for DS, DC, CS, RL, and HC, which in turn were not different from those of TS (P>.05). At 7 days, no differences (P>.05) were found among the WS values for DC, HC, RL, DS, and CS; and TS presented WS values that were no different than those from RL, DS, and CS (P>.05). At 14 days, CC showed the lowest WS values (P<.05). No differences (P>.05) were found among the values for DC, DS, HC, and RL. No significant differences in WS values was observed between RL and CS, whereas no differences in WS values were noted among materials CS, ST, and TS (P>.05) (Table 3).

For solubility (n=10), this study was adequately powered for both the factors "material" and "time" (over 99.5%; α=.05). ANOVA detected significant differences among the factors "material," "time," and the interaction between them (P<.001) (Table 4). Results of solubility (%) are presented in Table 5. Most of the evaluated materials did not show any change in solubility values along with the time intervals (P>.05), except for tissue conditioners VG and ST, which presented increased solubility only at 14 days of evaluation (P<.05) (Table 5).

Table 4. Summary of 2-way ANOVA of solubility

Source	*df*	Type III SS	MS	F	*P*
Material	8	14456.80	1807.099	992.066	<.001
Time	3	92.06	30.687	16.850	<.001
Material×time	24	215.43	8.976	4.929	<.001
Error	324	590.06	1.821		

MS, mean square.

Comparisons among materials demonstrated that, in all immersion time intervals, the greatest mean solubility was observed for VG ($P<.05$). At 3 days, no differences were found among the solubility values for ST, CS, RL, and CC ($P>.05$). In addition, DC, HC, DS, TS, CC, RL, and CS had the lowest solubility values, without differences from each other ($P>.05$). At 5 days, no significant differences ($P>.05$) were found among the solubility values for DC, HC, DS, TS, CS, RL, and CC, which in turn were not different from those of ST ($P>.05$). At 7 days, no statistically significant differences were found among CC, CS, TS, RL, DS, DC, and HC ($P<.05$), which exhibited the lowest mean values of solubility. At 7 and 14 days, ST showed higher solubility values than the other materials, except for VG ($P<.05$). At 14 days, there were no differences among the values of CC, CS, and RL ($P>.05$), and the values for CS, RL, TS, DS, DC, and HC also did not differ significantly ($P>.05$) (Table 5).

Table 5. Mean ±standard deviation percent values of solubility for the interim resilient materials in the evaluation periods

Material	3 days	5 days	7 days	14 days
Coe-Comfort	1.89 ±0.30^{Abc}	2.14 ±0.37^{Abc}	2.14 ±0.56^{Ac}	3.35 ±0.70^{Ac}
Dura Conditioner	0.28 ±0.08^{Ac}	0.34 ±0.15^{Ac}	0.47 ±0.08^{Ac}	0.57 ±0.11^{Ad}
Dentusoft	0.76 ±0.36^{Ac}	0.86 ±0.11^{Ac}	0.64 ±0.22^{Ac}	0.83 ±0.12^{Ad}
Visco-gel	20.30 ±4.26^{Ba}	21.35 ±3.30^{Ba}	22.39 ±3.81^{Ba}	23.59 ±2.24^{Aa}
Softone	4.59 ±0.63^{Bb}	4.09 ±1.60^{Bb}	4.74 ±1.80^{Bb}	8.80 ±1.15^{Ab}
Hydro-Cast	0.38 ±0.17^{Ac}	0.42 ±0.22^{Ac}	0.41 ±0.09^{Ac}	0.53 ±0.09^{Ad}
Rite-Line	1.91 ±2.62^{Abc}	1.29 ±0.00^{Ac}	1.32 ±0.09^{Ac}	1.84 ±0.27^{Acd}
Trusoft	1.10 ±0.31^{Ac}	1.06 ±0.58^{Ac}	1.43 ±0.38^{Ac}	1.59 ±0.46^{Ad}
Coe-Soft	2.06 ±0.32^{Abc}	1.25 ±0.28^{Ac}	1.65 ±0.30^{Ac}	2.13 ±0.23^{Acd}

Different superscript letters (uppercase: within row; lowercase: within column) indicate significant differences ($P<.05$).

DISCUSSION

The research hypothesis stating that the WS and solubility of interim denture resilient liners vary among the different materials and according to the evaluation period was partially accepted. Both properties of the 9 tested materials usually varied from each other, and in some cases, the percentage values increased according to the time intervals, especially after 7 days.

Tissue conditioners are ideally recommended for 3 to 4 days and should not be used for longer than 2 weeks.[5,23,24] According to the manufacturers, the interim resilient liners TS and CS can be used for up to 6 months because they contain smaller quantities of plasticizer and alcohol than tissue conditioners. However, the mean clinical lifespan during which these materials may adequately play their role is 14 days.[22,23]

Surprisingly, the present results revealed that the tissue conditioner CC exhibited low percentages of WS compared with those of all materials analyzed and did not exhibit changes in this property throughout the 14 days, as observed for the resilient liners TS and CS. Conversely, for the other materials, a significant increase was noted in WS between 7- and 14-day periods. These results may be attributed to the different compositions of interim denture resilient liners tested. However, the manufacturers of these products presented little or no description as to the type or concentration of plasticizers and alcohol in the liquids, and even when there was information listed on the Material Safety Data Sheet (MSDS), different formulations were described for the same material.

Phthalate plasticizers are added to the liquids of acrylic resin resilient materials to reduce the WS due to their high hydrophobicity and potential to fill the microspaces present in the polymer. However, this ability is limited over time for interim resilient materials, which present high concentrations of plasticizers that are rapidly leached into the external aqueous medium.[17] Other factors contribute to the WS observed in these materials, especially the polymer hydrophilicity,[19] which increases with its number of hydrocarbon groups.[33] According to the MSDSs, the powders of all products evaluated in this study are composed of poly(ethyl methacrylate) (associated or not with poly[methyl methacrylate]), which presents higher levels of WS in relation to other polymers as poly(*n*-butyl methacrylate).[9,33] The powder of CC contains up to 10% zinc undecylenate, an antifungal component with high-molecular weight (431.91 g/mol) that impairs WS by the polymer, which presents low-molecular weight in the case of poly(ethyl methacrylate) of the tested materials (114.14 g/mol). Even though CS also contains zinc undecylenate, its concentration in the polymer matrix is lower (±5%) than that present in CC. This may explain the smaller WS observed for CC, as well as the stability of this property over time. Besides hydrophilicity and low-molecular weight of poly(ethyl methacrylate) of the tested materials, water diffusion inside the matrix is facilitated by its low density, resulting from the smaller entanglement of polymeric chains.[35] This phenomenon may also be favored during manipulation of the powder-to-liquid ratio, which contributes to the appearance of micropores by the incorporation of air bubbles.[20] WS also involves the mechanism of adsorption; that is, the formation of hydrogen bonds between water and carboxyl groups, although esterified, depends on the polymer chemical composition.[8]

The interim resilient liners TS and CS and the tissue conditioners CC, RL, DC, HC, and DS did not present alterations in solubility over the 14 days of water

immersion. Surprisingly, in this period, DC, HC, and DS presented the lowest numerical means of solubility. According to MSDS, the liquid of DC is basically composed of 2-etilhexil diphenyl phosphate (90%-95%), a compound of higher molecular weight (362.40 g/mol) than dibutyl phthalate (278.34 g/mol), the plasticizer contained in most of the materials tested in this investigation. According to the MSDS and a study by Hong et al,[24] the liquid of HC contains benzyl butyl phthalate (80%-90%), also with higher molecular weight (312.37 g/mol), ethanol (10%-20%), and acetone (1%-5%). Although the MSDS does not describe its formulation, Bail et al. (22) related that the DS liquid is composed by dibutyl phthalate and alcohol without specifying the concentrations of these components. The lower the molecular weight of the plasticizer and the greater the concentration of this compound and ethyl alcohol in a resilient material, the greater will be its weight loss and percentage of solubility during water storage.[5] The molecular weights of HC and DC plasticizers are greater than that of dibutyl phthalate (278.34 g/mol), present in most interim resilient liners used in this study, which may explain the lowest solubility values observed for these materials.

The high-molecular weight of the plasticizer in HC reduces its leaching and, despite the great ethanol loss in up to 24 hours that alters its dynamic properties,[24] this material may be clinically used for up to 14 days. Results of low solubility and stability of this property throughout the evaluation period observed for DS suggest lower concentration of dibutyl phthalate, as well as alcohol, than in the other materials in this study that presented the same plasticizer. According to the manufacturer, the liquid of RL is composed of a dialkyl phthalate plasticizer (<80%), yet without specification of its type, not showing the presence of ethyl alcohol. Thus, in addition to the absence of alcohol, the main plasticizer of this material probably has a sufficiently high-molecular weight, explaining the low solubility of RL during the 14 days of water immersion.

According to the MSDS, the liquid of TS contains ethanol (15%-25%) and benzyl butyl phthalate (50%-85%), with higher molecular weight than dibutyl phthalate, which might have favored the low solubility maintained throughout the evaluation. Even though the MSDS and Safety Data Sheet (SDS) describe the presence of benzyl salicylate (25%-50%) and ethyl alcohol (10%-20%) in the liquid of CS, previous studies identified large quantities of dibutyl phthalate in its composition (49.7%[17] and 30 to 60%,[15] respectively). According to the MSDS, SDS, and prior studies,[11,24] the liquid of CC contains mainly benzyl benzoate (50%-87.3%) and ethyl alcohol (7.03%-10%). Even though CC and CS have high concentrations of plasticizer with low-molecular weight (benzyl salicylate: 228.24 g/mol; benzyl benzoate: 212.08 g/mol), the materials may have presented greater retention of components in its structure over the water immersion period, suggesting that leaching of phthalate is not related only to the greater initial absolute concentration of the plasticizer in the polymeric matrix.[34]

At 7 and 14 days, ST had statistically greater solubility in relation to the other tested materials, except for VG, which may be associated with the high concentrations of plasticizer of low-molecular weight (45%-55% of dibutyl phthalate) and ethyl alcohol (15%-25%), according to the composition described in the SDS. These results suggest ST is indicated for use as functional impression material or as tissue conditioner for up to 1 week, corroborating the findings of Elsemann et al,[34] who demonstrated that between 3 and 7 days there was no significant loss of phthalate from this material. Similarly, Shylesh et al[6] observed the best properties of dimensional change, plasticity, and flow after 30 minutes of mixture for ST among all the tested materials.

The greater percentage of solubility among the materials was observed for VG in all evaluation periods, with differences ranging from 4.5 (ST) to 100 times (DC). Notwithstanding, VG presented stability of solubility in up to 7 days of evaluation, which would confirm its indication for use in tissue conditioning due to its high initial viscosity, high elasticity, and small change in this property in up to 1 week in water.[4] Jones et al[17] identified contents of 86.9% butyl phthalate butyl glycolate, 8.2% dibutyl phthalate, and 4.9% ethanol in the liquid of VG, whereas the MSDS describes these compositions as 50% to 100% of triethyl citrate (276.28 g/mol) and 2.5% to 10% of ethyl alcohol. The high solubility values observed for VG in this study are difficult to explain, considering the low percentage of alcohol, besides the fact that its main plasticizer probably has a high-molecular weight. The material may have had greater retention of components in its structure during the water immersion period.[34] The high WS and solubility observed for VG may also be related to the experimental conditions such as volatility of ethanol from the material liquid during preparation of specimens[25] and even the product batch.[17]

Within the present in vitro conditions, considering the results obtained for both properties analyzed, simultaneously, the best performance for functional impressions and tissue conditioning for up to 7 days was observed for materials CC, DC, HC, DS, RL, CS, and TS (WS, 2.23%-8.72%; solubility, 0.28%-2.14%). For interim relining, the tissue conditioner CC and the interim resilient liners TS and CS presented the best performance for WS (2.23%-7.35%) and solubility (1.06%-3.35%) regarding the low values maintained for up to 14 days. However, the WS and solubility values observed in this in vitro study should be carefully applied to the clinical conditions, because in these situations the material is subjected to cleaning and disinfection procedures adopted by the patient, as well as to thermal alterations, pH variations, and deformation by the occlusal load of the oral

environment, which contribute to faster loss of leachable components.[11,15,30] Thus, definitive evaluation of the performance of interim resilient liners by in vivo clinical studies is suggested.

CONCLUSIONS

Within the limitations of this in vitro study, the following conclusions were drawn:

1. At 14 days, the smallest WS among all materials was observed for CC ($P<.05$), followed by TS, ST, and CS, with no significant differences among them ($P>.05$). RL, DC, HC, and DS showed intermediate mean percentages with no significant differences at 14-day water immersion ($P>.05$).
2. WS in tissue conditioner CC and interim resilient liners CS and TS did not change over the 14 days ($P>.05$). All other tested materials presented with increased WS between 7 and 14 days ($P<.05$).
3. In all evaluation periods, the lowest mean values of solubility were observed for tissue conditioners DC, DS, HC, and RL and resilient liners TS and CS ($P>.05$).
4. At the 14-day interval, ST and VG exhibited increases in solubility ($P<.05$), whereas this property was not changed for the materials CC, DC, DS, HC, RL, TS, and CS ($P>.05$). Regardless of the evaluation period, VG presented the highest mean percentages of WS and solubility among all tested materials ($P<.05$).

REFERENCES

1. The glossary of prosthodontic terms. Ninth edition. J Prosthet Dent 2017;117(suppl 5):1-105.
2. Dorocka-Bobkowska B, Medyński D, Pryliński M. Recent advances in tissue conditioners for prosthetic treatment: a review. Adv Clin Exp Med 2017;26:723-8.
3. Iqbal Z, Zafar MS. Role of antifungal medicaments added to tissue conditioners: a systematic review. J Prosthodont Res 2016;60:231-9.
4. Monzavi A, Siadat H, Atai M, Alikhasi M, Nazari V, Sheikhzadeh S. Comparative evaluation of physical properties of four tissue conditioners relined to modeling plastic material. J Dent 2013;10:506-15.
5. Murata H, Kawamura M, Hamada T, Saleh S, Kresnoadi U, Toki K. Dimensional stability and weight changes of tissue conditioners. J Oral Rehabil 2001;28:918-23.
6. Shylesh KB, Hallikerimath RB, Rajeev VV, Ganesh S, Meenakshi S. Evaluation of physical properties of tissue conditioning materials as used in functional impression: a lab study. J Int Oral Health 2013;5:20-7.
7. Skupien JA, Valentini F, Boscato N, Pereira-Cenci T. Prevention and treatment of *Candida* colonization on denture liners: a systematic review. J Prosthet Dent 2013;110:356-62.
8. Canay S, Hersek N, Tulunoğlu I, Uzun G. Evaluation of colour and hardness changes of soft lining materials in food colorant solutions. J Oral Rehabil 1999;26:821-9.
9. Garg A, Shenoy KK. A comparative evaluation of effect on water sorption and solubility of a temporary soft denture liner material when stored either in distilled water, 5.25% sodium hypochlorite or artificial saliva: an in vitro study. J Indian Prosthodont Soc 2016;16:53-62.
10. Hermann C, Mesquita MF, Consani RL, Henriques GE. The effect of aging by thermal cycling and mechanical brushing on resilient denture liner hardness and roughness. J Prosthodont 2008;17:318-22.
11. Graham BS, Jones DW, Sutow EJ. Clinical implications of resilient denture lining material research. Part II: Gelation and flow properties of tissue conditioners. J Prosthet Dent 1991;65:413-8.
12. Mohammed HS, Singh S, Hari PA, Amarnath GS, Kundapur V, Pasha N, et al. Evaluate the effect of commercially available denture cleansers on surface hardness and roughness of denture liners at various time intervals. Int J Biomed Sci 2016;12:130-42.
13. El-Hadary A, Drummond JL. Comparative study of water sorption, solubility, and tensile bond strength of two soft lining materials. J Prosthet Dent 2000;83:356-61.
14. Kazanji MN, Watkinson AC. Soft lining materials: their absorption of, and solubility in, artificial saliva. Br Dent J 1988;165:91-4.
15. Huh JB, Lim Y, Youn HI, Chang BM, Lee JY, Shin SW. Effect of denture cleansers on *Candida albicans* biofilm formation over resilient liners. J Adv Prosthodont 2014;6:109-14.
16. Leite VM, Pisani MX, Paranhos HF, Souza RF, Silva-Lovato CH. Effect of ageing and immersion in different beverages on properties of denture lining materials. J Appl Oral Sci 2010;18:372-8.
17. Jones DW, Sutow EJ, Hall GC, Tobin WM, Graham BS. Dental soft polymers: plasticizer composite and leachability. Dent Mater 1988;4:1-7.
18. Anusavice KJ, Zhang NZ, Shen C. Controlled release of chlorhexidine from UDMA-TEGDMA resin. J Dent Res 2006;85:950-4.
19. Kalachandra S, Kusy R. Comparison of water sorption by methacrylate and dimethacrylate monomers and their corresponding polymers. Polymer 1991;32:2428-34.
20. Braden M, Wright PS. Water absorption and water solubility of soft lining materials for acrylic dentures. J Dent Res 1983;62:764-8.
21. Qudah S, Huggett R, Harrison A. The effect of thermocycling on the hardness of soft lining materials. Quintessence Int 1991;22:575-80.
22. Bail M, Meister LM, Campagnoli EB, Jorge JH, Ban Mde C, Sanchez-Ayala A, et al. Histopathological changes by the use of soft reline materials: a rat model study. PLoS One 2014;9:e100293.
23. Hong G, Li Y, Maeda T, Mizumachi W, Sadamori S, Hamada T, et al. Influence of storage methods on the surface roughness of tissue conditioners. Dent Mater J 2008;27:153-8.
24. Hong G, Maeda T, Murata H, Sasaki K. The dynamic viscoelasticity and plasticizer leachability of tissue conditioners. Gerodontology 2012;29:284-91.
25. Murata H, Chimori H, Hong G, Hamada T, Nikawa H. Compatibility of tissue conditioners and denture cleansers: influence on surface conditions. Dent Mater J 2010;29:446-53.
26. Dinckal Yanikoglu N, Yesil Duymus Z. Comparative study of water sorption and solubility of soft lining materials in the different solutions. Dent Mater J 2004;23:233-9.
27. Goll G, Smith DE, Plein JB. The effect of denture cleansers on temporary soft liners. J Prosthet Dent 1983;50:466-72.
28. Lima JF, Maciel JG, Arrais CA, Porto VC, Urban VM, Neppelenbroek KH. Effect of incorporating antifungals on the water sorption and solubility of interim resilient liners for denture base relining. J Prosthet Dent 2016;115:611-6.
29. Sudhapalli S, Sudhapalli S. Time dependent effect of a denture cleanser on the sorption and solubility of four soft liners-an in vitro study. J Clin Diagn Res 2016;10:ZC100-3.
30. Yilmaz H, Aydin C, Bal BT, Ocak F. Effects of different disinfectants on physical properties of four temporary soft denture-liner materials. Quintessence Int 2004;35:826-34.
31. International Organization for Standardization. ISO 10139-2:1999 soft lining materials for removable dentures-Part 2: materials for long-term use. Geneva: ISO; 1999. Available at: http://www.iso.org/iso/catalogue_detail.htm?csnumber=50348. Accessed Sep 29, 2017.
32. American National Standards/American Dental Association. [ANSI/ADA] specification n. 12 denture base resins, 2002, revised [ANSI/ADA] standards/ADA specification n. 12 for denture base resins (R2007). New York: ANSI. Available online at: http://www.ada.org/830.aspx. Accessed September 29, 2017.
33. Hong G, Tsuka H, Maeda T, Akagawa Y, Sasaki K. The dynamic viscoelasticity and water absorption characteristics of soft acrylic resin materials containing adipates and a maleate plasticizer. Dent Mater J 2012;31:139-49.
34. Elsemann RB, Cosme DC, Souto AA, da Silva DF, de Mello JS, Shinkai RS. Degradation of tissue conditioners in complete dentures: an in situ study. Int J Prosthodont 2008;21:486-8.
35. Parr GR, Rueggeberg FA. Physical-Property comparison of a chairside- or laboratory-polymerized permanent soft-liner during 1 year. J Prosthodont 1999;8:92-9.
36. Leon BL, Del Bel Cury AA, Rodrigues Garcia RC. Water sorption, solubility, and tensile bond strength of resilient denture lining materials polymerized by different methods after thermal cycling. J Prosthet Dent 2005;93:282-7.

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Acknowledgments
The authors thank Heitor Marques Honório for assisting with the statistical analysis.

https://doi.org/10.1016/j.prosdent.2018.03.007