J Indian Prosthodont Soc (Jan-Mar 2014) 14(1):93–97
DOI 10.1007/s13191-013-0279-1

ORIGINAL ARTICLE

Creep and Stress Relaxation Behavior of Two Soft Denture Liners

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Received: 24 October 2012 / Accepted: 13 March 2013 / Published online: 21 March 2013

Abstract Numerous investigators stated the indications of soft denture lining materials; but no one determined the indications of these materials according to their chemical structure. The purpose of this investigation was to evaluate the viscoelastic properties of acrylic and silicon lining materials. This study investigated and compared viscoelastic properties of two resilient denture lining materials. Tested materials were laboratory processed; one of them was silicone-based liner product (Molloplast-B), and the other was plasticized acrylic resin (Vertex™ Soft). Twenty cylindrical specimens (10–20 mm in length, 11.55 mm in diameter) were fabricated in an aluminum mold from each material for creep and stress relaxation testing (the study of viscoelastic properties). Tests were performed by using the universal testing machine DY-34. Collected data were analyzed with *t* test statistics for statistically significant differences at the 95 % confidence level. There was a clear difference in creep and stress relaxation behavior between acrylic and silicone liners. Statistical study of Young's moduli illustrated that Vertex™ Soft was softer than Molloplast-B. On the other hand, the results explained that the recovery of silicone material was better than of acrylic one. The creep test revealed that the plasticized acrylic resin lining material exhibited considerable creep, whereas silicone-based liner exhibited elastic behavior. Besides, the stress relaxation test showed that relaxation of the plasticized acrylic resin material was bigger than of the silicone-based liner.

Keywords Creep · Stress relaxation · Soft denture liners

Clinical Implications. Acrylic soft denture liners can be used only for a short time to measure the injured mucosa, whereas silicone-based materials used as a permanent liners.

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Introduction

The use of resilient denture lining materials for denture prostheses in selected clinical situations has long been recognized [1]. These materials are often used in the treatment of traumatized denture- supporting mucosa and advanced resorption of the residual alveolar ridges; because they have a rehabiliting effect on unhealthy tissue by reducing and evenly distributing stresses on the mucosa of the basal seat [2–5].

The efficacy in the clinical use of resilient denture liners is considered to be influenced by their viscoelastic properties which characterize the ability of the material to achieve the cushioning effect [6, 7]. The viscoelastic properties of resilient denture liners have been examined by several investigators. Robinson and McCabe [6] studied creep behavior and stress relaxation of four silicone and acrylic soft lining materials. The study demonstrated that the acrylic resin materials exhibited considerable creep, whereas silicone liners exhibited elastic behavior and experienced much less creep. It, also, showed that both Coe Soft and Coe Super Soft (studied acrylic materials) were able to relax up to 80–90 % of the applied stress; and they achieved this level in 10–20 s. Murata et al. [8] investigated the dynamic viscoelastic properties of some permanent resilient denture liners. They found that acrylic resin material demonstrated viscoelastic behavior, so it revealed higher levels of cushioning or absorption of functional and

Table 1 Soft lining materials tested

Soft lining material	Symbol	Chemical type	Curing type	Manufacturer
Molloplast-B	M	Silicone-based material	Heat-curing	DETAX, Ettlingen, Germany.
Vertex^{TM} Soft	V	Plasticized acrylic resin material	Heat-curing	Vertex-dental, Zeist, The Netherlands

nonfunctional forces than silicone materials which behaved elastically.

Despite the clinical efficacy of soft denture liners, there is insufficient information regarding the effect of soft liners' chemical structure on load distribution and absorption in denture supporting tissues.

The purpose of this study was to evaluate the creep and stress relaxation behavior of two resilient denture liners of different chemical structures (silicone and acrylic).

Materials and Methods

Soft lining materials involved in this study were of two chemical types, plasticized acrylic resin and silicone-based materials. The materials and the manufacturers are summarized in Table 1.

Preparation of Specimens

Soft materials were packed in an aluminum split mold, (10–20 mm) in length and (11.55 mm) in diameter, by means of a spatula. The materials were processed in accordance with the manufacturer's instructions.

Ten cylindrical specimens were fabricated from each material for creep testing, and ten for stress relaxation test.

Method of Test

Creep Test

The specimen was loaded by means of universal testing machine (DY-34 ADAMEL LHOMARGY, FRANCE) to a constant stress (0.2 MPa), and changes in strain were measured continuously for (t) time which ranged from 300 to 1,200 s according to the nature of the tested material.

The constant stress value was selected in accordance with the study of McCarthy et al.[9] which investigated the distribution of the masticatory forces on the supportive surface of the denture which were in range of 0.0–0.21 MPa.

Stress Relaxation Test

The specimen was loaded by means of the testing machine (DY-34) to a strain of 15 %, and changes of stress were registered through (t) time which in range of 300–600 s.

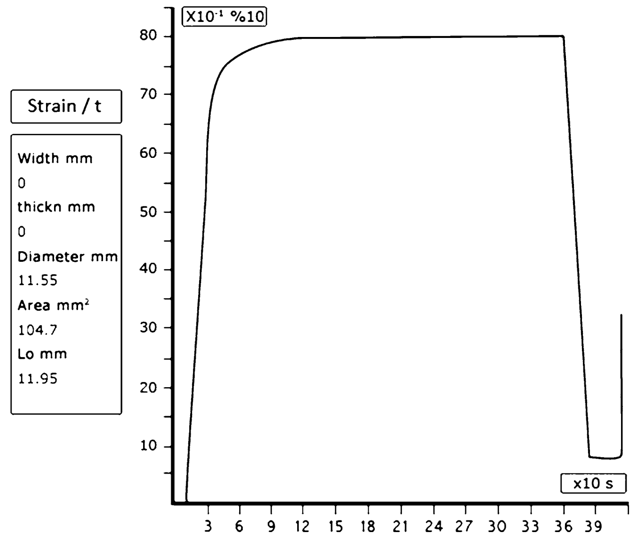

Fig. 1 Creep curve of Molloplast-B

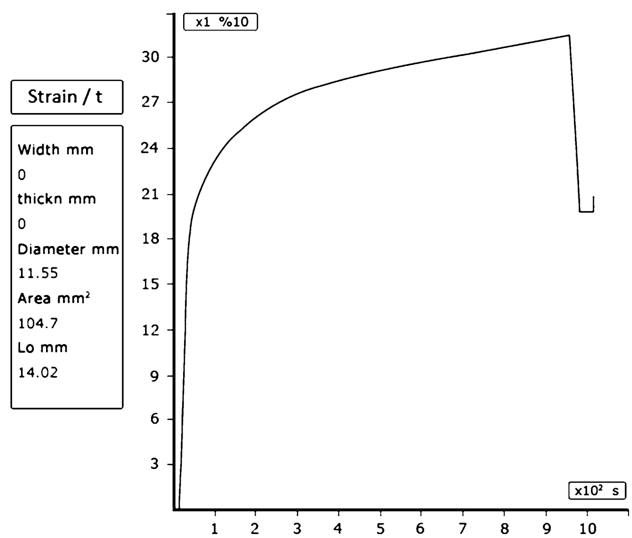

Fig. 2 Creep curve of Vertex^{TM} Soft

Results

Creep graphs of tested materials are illustrated in Figs. 1 and 2; whereas stress relaxation graphs are shown in Figs. 3 and 4.

Percentage of components of the total deformation in silicone-based material (M) were recorded as following: percentage of instantaneous elastic deformation (ε_{ei}) = 88.79,

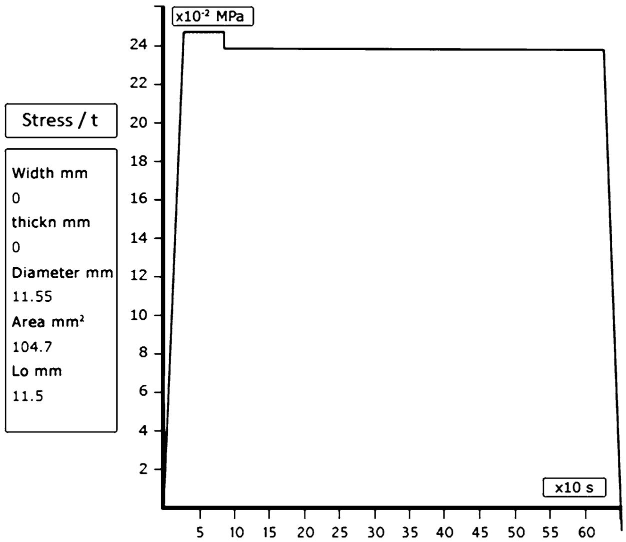

Fig. 3 Stress relaxation curve of Molloplast-B

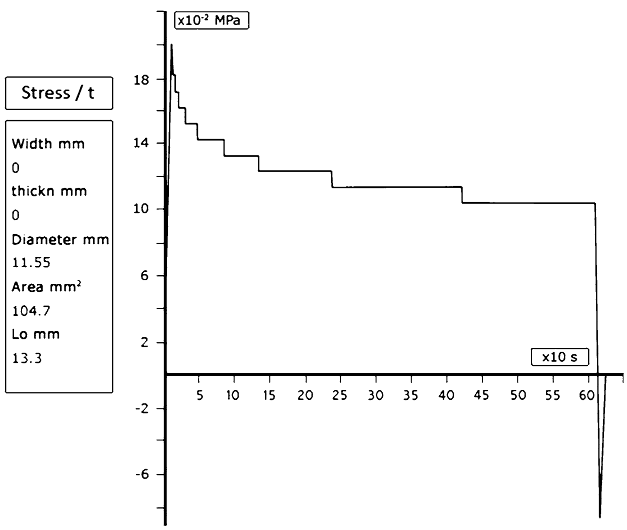

Fig. 4 Stress relaxation curve of Vertex^{TM} Soft

percentage of delayed elastic deformation (ε_{ed}) = 11.21, and viscous deformation (ε_v) $\approx$ 0; while ε_{ei}, ε_{ed}, and ε_v in plasticized acrylic lining material were (58.13), (21.19), (20.69) respectively.

Statistical study revealed that Young's modulus (E_0) and apparent Young's modulus (E_{ap}) of Molloplast-B differed significantly from E_0 and E_{ap} of Vertex^{TM} Soft at the 95 % confidence level (Tables 2, 3).

Also, it was clear, that there were important differences between the percentage of residual stresses of two tested materials at the studied times (at 5 s $t = 71.945$ and $p < 0.05$; at 20 s $t = 29.877$ and $p < 0.05$; at 60 s $t = 22.883$ and $p < 0.05$; at 120 s $t = 20.747$ and $p < 0.05$; at 300 s $t = 19.473$ and $p < 0.05$).

Discussion

Creep Test

When curves of strain changes were studied it was noticeable that the acrylic soft lining material had a special characteristic behavior which differed from the behavior of the silicone-based material. Creep curves of acrylic lining material demonstrated the characterized behavior of viscoelastic materials, because the strain increased when the material was subjected to a constant stress for a given time (Fig. 1).

Creep curves of silicone-based material showed the characterized behavior of elastic materials, since the strain increased up to a certain level when the material was subjected to a constant stress, then it became steady after a short time (Fig. 2).

It was apparent that the curves of these materials included three parts, representing three components of the resulted deformation. They are instantaneous elastic deformation (ε_{ei}), delayed elastic deformation (ε_{ed}), and viscous deformation (ε_v). Percentage of viscous deformation reached to 20.69 % in plasticized acrylic material, whereas it was $\sim$0 % in silicone-based material. That means the acrylic lining material failed to complete recovery after the compression tests, whereas the silicone exhibited complete recovery.

The flow of a viscoelastic material is expressed by viscous portion of the creep curve and is related to the viscosity of the material. The creep curves of the plasticized acrylic and silicone-based materials illustrated that the flow of Vertex^{TM} Soft material is recognizable but it was very low in Moloplast-B. Clinically, the low viscosity of the plasticized acrylic liner allows it to adapt to the supporting area during treatment of abused tissues. So, it probably would be benefit as treatment liner. On the opposite side, the silicone-based liner with low flow may be used as a permanent liner because changes in occlusion would be minimized over its life.

The low values of Young's moduli (E_0) indicated that all tested materials were soft in comparison of other prosthetic or restorative materials such as acrylic resins of denture bases ($E_0 = 2$–3×10^3 MPa), composites ($E_0 = 5$–15×10^3 MPa), or vital dental materials such as enamel or dentin ($E_{0(enamel)} = 46$–84×10^3 MPa, $E_{0(dentin)} = 12$–18×10^3 MPa)[10, 11].

Statistical study of Young's moduli illustrated that Vertex^{TM} Soft was softer than Molloplast-B.

The present study revealed that the viscoelastic behavior of the oral mucosa is close to the viscoelastic behavior of soft acrylic material, but the behavior of this material would be changed after sometime, because it contains a high percent of plasticizers which may be leached in saliva

Table 2 Independent samples test for E_o

		Levene's test for equality of variances		*t* test for equality of means						
		F	Sig.	*t*	df	Sig. (2-tailed)	Mean difference	Std. error difference	95 % confidence interval of the difference	
									Lower	Upper
E_o	Equal variances assumed	7.264	0.015	30.733	18	0.000*	1.584800	0.051567	1.476461	1.693139
	Equal variances not assumed			30.733	9.201	0.000*	1.584800	0.051567	1.468534	1.701066

* Statistically significant ($p < 0.05$)

Table 3 Independent samples test for E_{ap}

		Levene's test for equality of variances		*t* test for equality of means						
		F	Sig.	*t*	df	Sig. (2-tailed)	Mean difference	Std. error difference	95 % confidence interval of the difference	
									Lower	Upper
E_{ap}	Equal variances assumed	12.805	0.002	41.871	18	0.000*	1.568600	0.037463	1.489894	1.647306
	Equal variances not assumed			41.871	11.087	0.000*	1.568600	0.037463	1.486224	1.650976

* Statistically significant ($p < 0.05$)

extensively, and therefore the material becomes hard [12, 13]. Loss of resiliency in this material also may result from continued material polymerization over time, or from material degradation caused by salivary or chemical compounds in the oral environment [14]. The viscoelastic behavior of the silicone-based liner differed from the behavior of oral mucosa, but its recovery was complete and instantaneous as previously stated.

The material which deforms viscously have the ability to absorb functional and nonfunctional forces [8], therefore the plasticized acrylic soft material not the silicone-based one has this advantage.

Stress Relaxation

Relaxation curves of acrylic soft liner showed a noticeable reduction in stresses when the material was subjected to a constant strain for a given time.

Statistical analysis explained that the relaxation rate of Vertex™ Soft was more than of Molloplast-B, and it may be attributed to the existence of plasticizers in the structure of the first material. Relaxation curves of silicone-based liner confirmed this result, they revealed that the relaxation rate of this material was so low in comparison of the relaxation rate of acrylic soft liner.

Stress relaxation expresses the reduction of Young's modulus, thus silicone material can conserve its primary Young's modulus, whereas acrylic soft material submit to a big reduction in its primary Young's modulus. McCarthy and Moser [15] stated that when Young's modulus of a material decreases continuously, it can achieve a massage effect. Therefore the acrylic soft material not silicone-based one can do that. This result is in agreement with those of previous studies which showed that application of permanent acrylic resilient denture liner to mandibular complete dentures decreases complications during the first patient visit after delivery session [16], and improves significantly the patient's satisfaction [17].

On the other side, accumulation of irreversible viscous deformation leads to acrylic liner of bad fitting. So, it is advisable to use acrylic soft lining material for short time.

Conclusions

Within the limits of this study, the following conclusions were made:

1 The study demonstrated that acrylic soft material exhibited viscoelastic behavior, whereas silicone-based liner exhibited elastic behavior.
2 Recovery of silicone-based material was better than of acrylic soft lining material.
3 The viscoelastic behavior of oral mucosa is like to the viscoelastic behavior of soft acrylic liner.
4 It is advisable to apply acrylic soft material on traumatized mucosa because it is able to achieve the cushioning effect, whereas silicone material cannot do that.
5 It is favorable to use acrylic soft material for short time to perform the massage effect.

Acknowledgments I acknowledge Damascus University for the financial support of the study. I would like to thank the statistician Muhammad Zaino who helped to perform the statistical study of the research. Also I appreciate the help from Professor Rafee Jabra for his helpful assistance in achieving creep and stress relaxation tests.

Conflict of Interest The current research is free of conflict of interest.

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