

RESEARCH AND EDUCATION

## Changes in hardness of addition-polymerizing silicone-resilient denture liners after storage in artificial saliva



Agnieszka Nowakowska-Toporowska, PhD,<sup>a</sup> Krystyna Malecka, PhD,<sup>b</sup> Zbigniew Raszewski, PhD,<sup>c</sup> and Włodzimierz Wieckiewicz, PhD<sup>d</sup>

Resilient denture liners are widely used to improve the fit of removable dentures and prevent excessive pressure on the supporting tissues. Soft relining protects the oral mucosa and also prevents the bone from resorption,<sup>1</sup> which is a result of excessive pressure of the hard acrylic resin denture material. The use of resilient denture liners helps relieve pain, improves mastication ability, and, in turn, facilitates the patient's adaptation process.<sup>2,3</sup> In addition, relining materials are beneficial during the healing period after implant placement because they relieve pressure and promote osseointegration.<sup>4-7</sup> Direct relining is an effective and efficient way of improving the patient's quality of life.<sup>8</sup>

Soft relining materials should have appropriate physical qualities regarding homogenous stress distribution on oral tissues, high adhesion to the poly(methyl methacrylate) of the denture base, low sorption and solubility in saliva and other fluids, stable color, and appropriate hardness. Addition-polymerizing silicone resilient denture liners have favorable properties

### ABSTRACT

**Statement of problem.** The hardness of silicone resilient denture liners was reported to be more stable than that of acrylic resin resilient denture liners. However, the changes in hardness of these materials in artificial saliva are unclear.

**Purpose.** The purpose of this in vitro study was to evaluate changes in the hardness of addition-polymerizing silicone-resilient denture liners for long-term use after storage in artificial saliva.

**Material and methods.** Four addition-polymerizing silicone resilient denture liners were tested: GC Reline Soft, Elite Soft Relining, Megabase, and Mucopren Soft. All were long-term relining materials of the soft type. Fifteen disk-shaped specimens were prepared for each of the tested materials (40 mm in base diameter, 8 mm in thickness). Their initial hardness was assessed with a Shore A durometer, after which they were stored in artificial saliva at a temperature of 37°C. Hardness was examined after 7, 30, and 90 days. Statistical analysis was performed using parametric ANOVA for dependent and independent variables and Tukey honest significant difference (HSD) post hoc tests ( $\alpha=.05$ ).

**Results.** All resilient denture liners increased in hardness during the experiment. The change was least for Elite Soft Relining, and GC Reline Soft was the hardest material. Initially, Megabase and Mucopren Soft were significantly softer than the other 2 materials, but their hardness increased rapidly after the first 7 days of specimen conditioning, achieving values close to Elite Soft Relining.

**Conclusions.** Within the limitations of the study, room temperature vulcanizing addition-polymerizing polyvinyl siloxanes of the soft type have different initial hardness, and this changes with storage time in artificial saliva at the temperature of the oral cavity. (J Prosthet Dent 2019;121:317-21)

compared with acrylic resin-based resilient denture liners.<sup>9-13</sup>

The initial hardness of soft relining materials of different chemical compositions ranges between 25 and 95 degrees Shore (Sh) A.<sup>14</sup> Ideally, their elasticity should remain constant with aging. The increase in hardness of resilient denture liners may be a result of ongoing polymerization

Supported by statutory grant no. PbmN/26 from Wrocław Medical University, Wrocław, Poland.

<sup>a</sup>Research Assistant, Department of Prosthodontics, Wrocław Medical University, Wrocław, Poland.

<sup>b</sup>Research Associate Professor, Department of Drug Technology, Wrocław Medical University, Wrocław, Poland.

<sup>c</sup>Laboratory Technician, Department of Prosthodontics, Wrocław Medical University, Wrocław, Poland.

<sup>d</sup>Professor, Department of Prosthodontics, Wrocław Medical University, Wrocław, Poland.

## Clinical Implications

Proper initial hardness and long-lasting elasticity of the relining material are essential for successful denture relining. Elite Soft Relining may be the most clinically favorable relining material in terms of hardness stability

and an increasing number of cross-linking bonds between polymer chains.<sup>15</sup> Hardening with time has been reported both for acrylic resin and silicone-resilient denture liners but is less pronounced for the silicone materials.<sup>16-19</sup>

Room temperature vulcanizing (RTV) addition-polymerizing polyvinyl siloxanes (PVS) of the soft type are contemporary relining materials for long-term use. Their initial hardness ranges between 25 and 50 degrees Sh A, and should not exceed 55 degrees Sh A 28 days after the denture is relined.<sup>20</sup>

The Young elastic modulus and hardness of materials are correlated.<sup>21</sup> The elasticity of soft relining materials influences their pressure-absorbing action.<sup>22</sup> According to Sato et al,<sup>23</sup> if the hardness and elasticity of these materials exceed those of the oral mucosa, the pressure on oral tissues increases disadvantageously. Therefore, the hardness of the relining material should remain unchanged during denture use and should be carefully selected for the clinical situation. To facilitate the clinical choice of resilient denture liner, a comparative evaluation of initial hardness and the dynamics of change over time is needed.

The elasticity-retaining ability of silicone-resilient denture liners has been investigated with contradictory results. Some studies have stated that the hardness of silicone-based relining materials does not change over time,<sup>11,18</sup> whereas others report an increase in material stiffness.<sup>9,19,24,25</sup> In most of these experiments, the specimens were stored in distilled water. Results obtained after conditioning in artificial saliva are considered more clinically relevant.<sup>26</sup> The authors are unaware of any evaluation of hardness changes in an artificial saliva environment.

The null hypothesis of this study was that all tested materials would have equal initial hardness and that this property would remain constant with time after conditioning in artificial saliva at 37°C.

## MATERIAL AND METHODS

Four commercially available addition-polymerizing silicone-resilient RTV PVS denture liners were tested in this comparative in vitro study: Elite Soft Relining; Zhermack SpA, GC Reline Soft; GC Corp, Megabase; Dreve GmbH, and Mucopren Soft; Kettenbach GmbH. All are soft type for long-term use. Pilot testing of specimens of different

**Table 1.** Artificial saliva composition

Constituent	Concentration (g/L)
Xanthan gum	0.92
Potassium chloride	1.2
Sodium chloride	0.85
Magnesium chloride	0.05
Calcium chloride	0.13
Dipotassium hydrogen orthophosphate	0.13
Methyl p-hydroxybenzoate	0.35

thicknesses revealed that to obtain objective results using a Shore A durometer, the specimen thickness should be at least 6 mm and all measurements should be performed at least 12 mm from their edges.<sup>27</sup> For Shore A hardness examination, disk-shaped specimens were prepared with a base diameter of 40 mm and a height of 8 mm. Specimens were prepared using metal molds and were polymerized according to the manufacturer's instructions for a chairside procedure. For each of the tested materials, 15 specimens were made.

The initial hardness of the specimens was assessed, and they were stored in artificial saliva (Table 1) at 37°C to simulate the oral cavity conditions.<sup>28</sup> The artificial saliva solution was changed weekly, and hardness was examined after 7, 30, and 90 days. The measurements were conducted in the central area of the specimens at least 12 mm from their borders. During all measurements, the specimens were placed on a flat base, and the hardness tester was lowered gradually until the indenter touched the surface of the specimen. The Shore A values were recorded after 5 seconds of loading.<sup>20</sup> In the experiment, a Shore A durometer was used (Shore Scale Durometer Hardness Tester DIN 53505 ISO R868 ASTM D2240).

The Young modulus of the tested materials was calculated from the Shore A hardness values obtained in this study with the use of the Gent equation<sup>21</sup>:

$E(\text{MPa})=0.0981(56+7.66s)/0.127505(254-2.54s)$ , where  $s$  is the Shore hardness.

A statistical analysis was performed using 2-way ANOVA and the Tukey honest significant difference (HSD) post hoc tests to assess whether the hardness level changed between the 4 time points for each liner separately and whether there were differences in hardness levels of the tested materials at each of the tested time points ( $\alpha=.05$ ).

## RESULTS

Significant ( $P<.001$ ) interactions were found between the tested materials and time points regarding both the Shore A hardness (Table 2) and Young modulus (Table 3). The initial hardness of the tested materials varied between  $28.1 \pm 0.6$  Sh A degrees and  $48.3 \pm 2.0$  Sh A degrees. The hardness of all materials changed at

**Table 2.** Two-way ANOVA results for comparison of hardness values

	SS	df	MS	F	P
Absolute term	492864.1	1	492864.1	363322.3	<.001
Material	7365.5	3	2455.2	1809.9	<.001
Error	76.0	56	1.4		
Time	5617.5	3	1872.5	1349.5	<.001
Time×Material	2245.9	9	249.5	179.9	<.001
Error	233.1	168	1.4		

MS, mean square; SS, sum of squares.

different tested time points (Fig. 1). All liners increased in hardness during the experiment. For Elite Soft Relining, the increase occurred only during the first 7 days of the experiment, and afterward, Shore A hardness remained stable returning to its initial values. This material had the most constant hardness over time (43.3-44.9 Sh A degrees). For all other materials, hardness increased at the time points. GC Reline Soft was the hardest material initially and during the whole experiment (48.3-58.3 Sh A degrees). After 30 days, its hardness no longer increased. At the first hardness assessment, Megabase and Mucopren Soft were significantly softer than the aforementioned materials, but after the first 7 days of specimen conditioning, their hardness increased rapidly with values close to those of Elite Soft Relining. After the 30-day and 90-day assessments, their hardness still increased, but less rapidly. The Young modulus at all tested time points had the following ranges: Elite Soft Relining (2.1-2.2 MPa), GC Reline Soft (2.5-3.7 MPa), Megabase (1.2-2.5 MPa), and Mucopren Soft (1.1-2.4 MPa) (Fig. 2). The Young modulus values increased between all tested time points for all materials, even though the Young modulus of Elite Soft Relining increased only after the 7-day measurement and subsequently returned to its initial values.

## DISCUSSION

The null hypothesis was rejected as significant differences were found in the initial hardness of the tested materials; none of them exhibited stable elasticity over time. Elite Soft Relining was the material with the least pronounced hardness changes. The increase in hardness of GC Reline Soft was 10 Sh A degrees during the whole time of the experiment, while for Megabase and Mucopren Soft, the total hardness increase was around 19 Sh A degrees. These materials were the least stable in terms of hardness. Elite Soft Relining and GC Reline Soft were more stable.

The elasticity of relining material should correspond with the resiliency of the oral mucosa, and the Young modulus of the relining material should not be lower than the underlying oral tissues.<sup>19</sup> This means that for less resilient oral mucosa, the use of a too soft relining material is contraindicated.

The Young modulus for all tested materials ranges between 1.1 and 3.7 MPa, whereas the mean elasticity

**Table 3.** Two-way ANOVA results for comparison of Young modulus values

	SS	df	MS	F	P
Absolute term	1302.035	1	1302.035	133976.9	<.001
Material	63.897	3	21.299	2191.6	<.001
Error	0.544	56	0.010		
Time	31.134	3	10.378	887.7	<.001
Time×Material	9.685	9	1.076	92.0	<.001
Error	1.964	168	0.012		

MS, mean square; SS, sum of squares.

modulus of denture-supporting mucosa is 1.3 to 5.0 MPa.<sup>6</sup> Therefore, Elite Soft Relining may be more suitable for patients with more resilient oral mucosa as its hardness is lower. GC Reline Soft as an overall harder material may be more advantageous for patients with less resilient oral tissues.

The present results vary from the data reported in the hardness examination of silicone-resilient denture liners, where one of the tested materials was Mucopren Soft.<sup>18</sup> These authors reported no hardness changes after 12 weeks of storage in both distilled water and artificial saliva. The difference between this and the present study may be due to different temperatures for specimen conditioning. In the previous experiments, the specimens were stored at room temperature, whereas our study was carried out at 37°C. This factor may influence the hardness changes of silicone resilient denture liners with increased polymerization and of cross-linking bonds at the higher temperature. Mutluay et al<sup>11</sup> also reported that silicone-based liners retained their hardness during cyclic loading, representing 1 year of denture use. The conditioning of the specimens was carried out at a temperature of 37°C in distilled water. The different results obtained in our experiment may be due to storage of the specimens in artificial saliva. The conditioning selected for this study was meant to accurately simulate the oral cavity environment because such conditions are more clinically relevant than storage in distilled water.<sup>26</sup>

The present results support the findings of Mancuso et al,<sup>9</sup> who reported a significant increase in the hardness of silicone resilient denture liners after thermocycling and of those obtained by Mese and Guzel<sup>19</sup> and Kim et al<sup>25</sup> for specimens conditioned in water at a temperature of 37°C. The findings of Khaledi et al<sup>24</sup> suggest that not only artificial saliva but also food simulating agents such as heptane, citric acid, and ethanol at the oral cavity temperature may influence soft silicone relining material, causing a significant increase in its hardness.

The results obtained in this study cannot be compared directly with those from other studies because the specimens varied in thickness, dimensions for Shore A hardness, and conditioning. In this in vitro study, conditions that the relining material is submitted to during intraoral use could not be completely

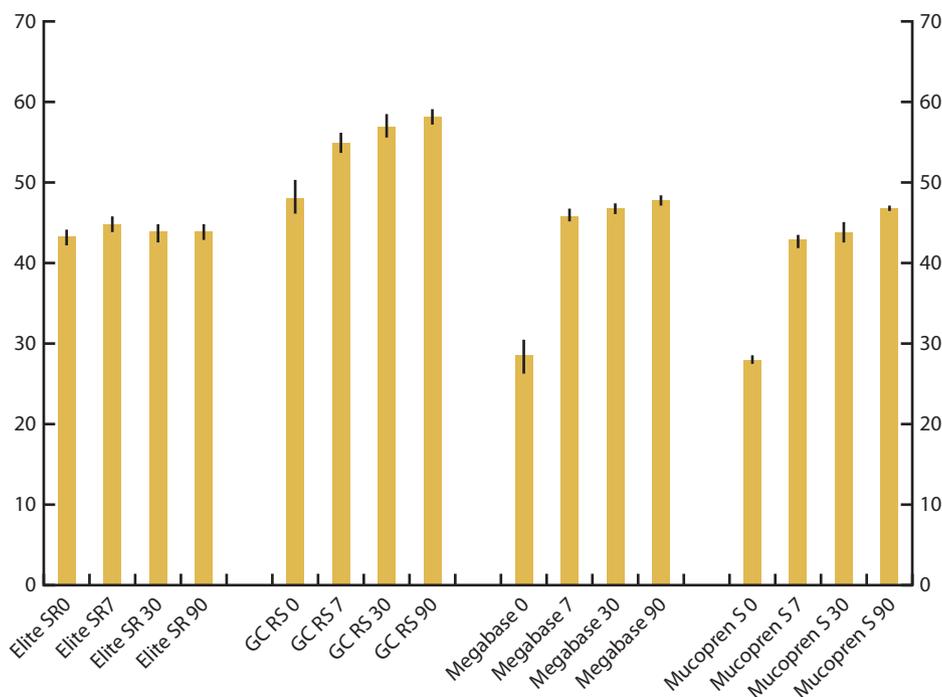


Figure 1. Hardness changes (Shore A degrees) of tested materials, mean ±standard deviation.

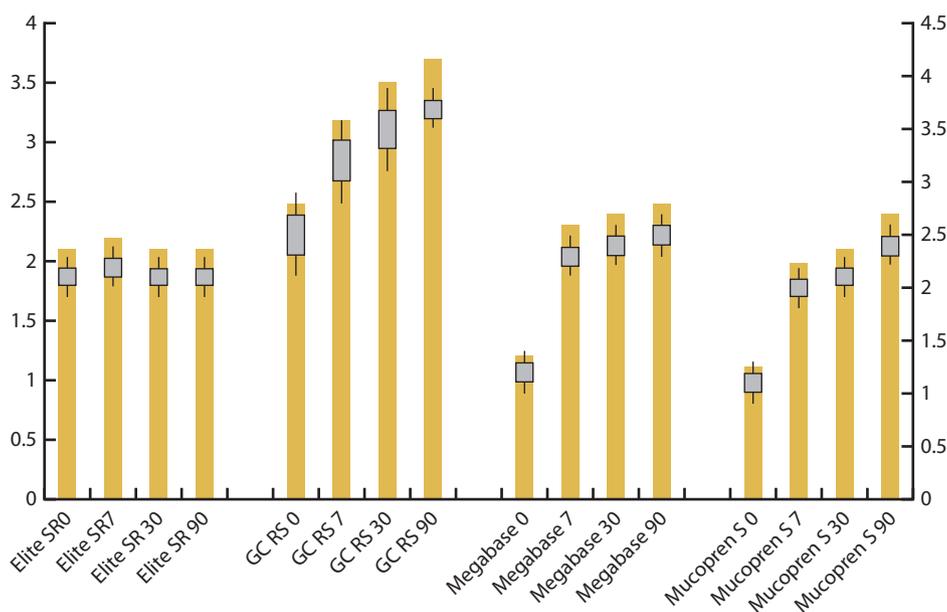


Figure 2. Young modulus (MPa) of tested materials, mean ±standard deviation.

reproduced. Factors such as dietary habits, disinfectant agents, and the denture storage conditions were not accounted for in this experiment and could have influenced the material hardness. The number of materials and time periods tested were limited. Further experimental and in vivo randomized examination of chairside addition-polymerizing silicone materials are required to determine their clinical usefulness.

### CONCLUSIONS

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

1. RTV addition-polymerizing PVS of the soft type have diverse initial hardness
2. Hardness changes over time of storage in artificial saliva at the temperature of the oral cavity.

## REFERENCES

- Maruo Y, Nishigawa G, Irie M, Oka M, Hara T, Suzuki K, et al. Stress distribution prevents ischaemia and bone resorption in residual ridge. *Arch Oral Biol* 2010;55:873-8.
- Kimoto S, Yamamoto S, Shinomiya M, Kawai Y. Randomized controlled trial to investigate how acrylic-based resilient liner affects on masticatory ability complete denture wearers. *J Oral Rehabil* 2010;37:553-9.
- Hayakawa I, Hirano S, Takahashi Y, Keh ES. Changes in the masticatory function of complete denture wearers after relining the mandibular denture with a soft denture liner. *Int J Prosthodont* 2000;13:227-31.
- Dos Santos MB, Consani RL, Mesquita MF. Influence of different soft liners on stress distribution in peri-implant bone tissue during healing period. A 3-D finite element analysis. *J Oral Implantol* 2013;39:575-81.
- Dos Santos MB, Da Silva Neto JP, Consani RL, Mesquita MF. Three-dimensional finite element analysis of stress distribution in peri-implant bone with relined dentures and different heights of healing caps. *J Oral Rehabil* 2011;38:691-6.
- Bacchi A, Consani RL, Mesquita MF, dos Santos MB. Influence of different mucosal resiliency and denture reline on stress distribution in peri-implant bone tissue during osseointegration. A three-dimensional finite element analysis. *Gerodontology* 2012;29:833-7.
- Dos Santos MB, Bacchi A, Consani RL, Mesquita MF. Influence of thickness and area of reline on the stress distribution in peri-implant bone during the healing period: a three-dimensional finite element analysis. *Gen Dent* 2012;60:231-6.
- Pisani MX, Malheiros-Segundo Ade L, Balbino KL, de Souza RF, ParanhosHde F, da Silva CH. Oral health related quality of life of edentulous patients after denture relining with a silicone-based soft liner. *Gerodontology* 2012;29:474-80.
- Mancuso DN, Goiato MC, Zuccolotti BC, Moreno A, Dos Santos DM, Pesqueira AA. Effect of thermocycling on hardness, absorption, solubility and colour change of soft liners. *Gerodontology* 2012;29:215-9.
- Pereira IP, Consani RL, Mesquita MF, Nóbilo MA. Photoelastic analysis of stresses transmitted by complete dentures lined with hard or soft liners. *Mater Sci Eng C Mater Biol Appl* 2015;55:181-6.
- Mutluay MM, Tezvergil-Mutluay A. The influence of cyclic stress on surface properties of soft liners. *Odontology* 2017;105:314-21.
- Niarchou A, Ntala P, Pantopoulos A, Polyzois G, Frangou M. Effect of immersion cleansing in color stability and hardness of soft denture reliners. *J Craniofac Surg* 2012;23:426-9.
- Nowakowska-Toporowska A, Raszewski Z, Wieckiewicz W. Color change of soft silicone relining materials after storage in artificial saliva. *J Prosthet Dent* 2016;115:377-80.
- Dootz ER, Koran A, Craig RG. Physical property comparison of 11 soft denture lining materials as a function of accelerated aging. *J Prosthet Dent* 1993;69:114-9.
- Tasopoulos T, Jagger RG, Jagger DC, Griffiths AE. Energy absorption and hardness of chair-side denture soft lining materials. *Eur J Prosthodont Restor Dent* 2010;18:189-94.
- Meşe A. Effect of denture cleansers on the hardness of heat- or auto-cured acrylic- or silicone-based soft denture liners. *Am J Dent* 2007;20:411-5.
- Kiat-Amnuay S, Gettleman L, Mekayarajananonth T, Khan Z, Goldsmith L. The influence of water storage on durometer hardness of 5 soft denture liners over time. *J Prosthodont* 2005;14:19-24.
- Więckiewicz W. Investigation of hardness of selected silicone elastomers used in postsurgical prosthesis lining. *ProtetStomatol* 2005;55:301-5.
- Mese A, Guzel KG. Effect of storage duration on the hardness and tensile bond strength of silicone- and acrylic resin-based resilient denture liners to a processed denture base acrylic resin. *J Prosthet Dent* 2008;99:153-9.
- International Organization of Standardization. ISO 10139-2:2016. Dentistry – Soft lining materials for removable dentures – Part 2: Materials for long-term use. Geneva: International Organization of Standardization 2016. Available at: <https://www.iso.org/standard/70317.html>.
- Meththananda IM, Parker S, Patel MP, Braden M. The relationship between Shore hardness of elastomeric dental materials and Young's modulus. *Dent Mater* 2009;25:956-9.
- Kawano F, Ohguri T, Koran A III, Matsumoto N, Ichikawa T. Influence of lining design of three processed soft denture liners on cushioning effect. *J Oral Rehabil* 1999;26:962-8.
- Sato Y, Abe Y, Okane H, Tsuga K. Finite element analysis of stress relaxation in soft denture liner. *J Oral Rehabil* 2000;27:660-3.
- Khaledi AA, Bahrani M, Shirzadi S. Effect of food simulating agents on the hardness and bond strength of a silicone soft liner to a denture base acrylic resin. *Open Dent J* 2015;26:402-8.
- Kim BJ, Yang HS, Chun MG, Park YJ. Shore hardness and tensile bond strength of long-term soft denture lining materials. *J Prosthet Dent* 2014;112:1289-97.
- Diñçal Yanikoglu N, YeşilDuymuş Z. Comparative study of water sorption and solubility of soft lining materials in the different solutions. *Dent Mater J* 2004;23:233-9.
- Siddiqui A, Braden M, Patel MP, Parker S. An experimental and theoretical study of the effect of sample thickness on the Shore hardness of elastomers. *Dent Mater* 2010;26:560-4.
- Preetha A, Banerjee R. Comparison of artificial saliva substitutes. *Trends Biomater Artif Organs* 2005;18:178-86.

**Corresponding author:**

Dr Agnieszka Nowakowska-Toporowska  
 Department of Prosthodontics  
 Wrocław Medical University  
 ul. Krakowska 26, 50-425 Wrocław  
 POLAND  
 Email: [agano125@gmail.com](mailto:agano125@gmail.com)

Copyright © 2018 by the Editorial Council for *The Journal of Prosthetic Dentistry*.  
<https://doi.org/10.1016/j.prosdent.2018.05.002>