Assessment of the Water Sorption and Hardness of Silicone and Acrylic-Based Soft Liners at Different Time Period: An *in vitro* Study

Mahinder Singh Chauhan¹, Roopsi Trivedi², Prabhu Raj Singh³,
Devendra Chopra⁴, Debajyoti Sarkar⁵, Hemant Suresh Thodsare⁶

¹Associate Professor, Department of Prosthodontics, Sharda School of Dental Sciences, Sharda University, Greater Noida, Uttar Pradesh, India; ²Assistant Professor, Department of Prosthodontics, Sardar Patel Postgraduate Institute of Dental and Medical Sciences, Lucknow, UP, India; ³Assistant Professor, Department of Prosthodontics, Sinhgad Dental College, Pune, Maharashtra, India; ⁴Professor, Department of Prosthodontics crown and Bridge, Saraswati Dental college and Hospital, Lucknow, UP, India; ⁵Assistant Professor, Department of Prosthodontics, Sardar Patel Postgraduate Institute of Dental and Medical Sciences, Lucknow, UP, India; ⁶Senior Lecture, Department of Prosthodontics, Sinhgad Dental College, Pune, Maharashtra, India.

ABSTRACT

Introduction: Ill-fitting dentures are treated with the use of tissue conditioners/ soft liners. They are applied to the surface of dentures to achieve equal force distribution and to improve denture retention.

Objectives: To assess the water sorption and hardness of acrylic resin-based auto-polymerized, heat-polymerized soft liners, and silicone-based auto-polymerized resilient liners at a different period.

Methods: After polymerisation, 30 discs of 3 soft liner material was stored in water at 37°C for 1 day, 1 week, 1 month, 6 months and 1 year. Later hardness test was determined using Shore-A Durometer tester. 30 specimens of respective soft liners were subjected to water sorption test at 1 day, 1 month, 6 months and after 1 year's period.

Results: The mean value for water sorption for self-cure, heat cure and silicone type was, 2.09, 0.08 and 2.04 respectively at one day and 2.12, 0.07 and 2.10mg respectively after one month, 2.16, 0.07, 2.10mg after 6 months and 2.18, 0.08, 2.10mg respectively after one year. The difference was statistically highly significant ($P < 0.001$). In a heat cure acrylic group, the hardness values at 5% level ($p < 0.05$) was significantly higher for all storage periods as compared to self-cure acrylic and self-cure silicone liner with different follow-ups.

Conclusion: The acrylic-based heat-polymerized (Super-soft) resilient liner had significantly higher hardness values than the auto polymerized acrylic and silicone resilient liners.

Key Words: Denture base, Hardness, Tissue conditioners, Soft liners, Water sorption

INTRODUCTION

The success of a complete denture depends on the fit of the denture, occlusion, esthetics, and masticatory functions. The denture is composed of artificial teeth attached to a denture base. The material most commonly used for denture base is acrylic resin. The soft lining material is used to moderate the force of occlusion on supporting tissues.¹ Resilient liner is advised in cases of; bony ridges with thin, non-resilient soft tissue coverage, persistent denture- sore mouth, ridges with tissue undercuts, to correct ill-fitting denture, to achieve more equal force distribution, and to reduce localized pressure.²⁻⁴

A resilient liner, as plasticized polyvinyl resin, was developed in 1945 and silicone-based materials were introduced in 1958. Ideal properties of resilient liners include resiliency, which is desired over a long period, and a bond to the denture base. The liner should also resist the absorption of oral fluids as well as the release of ethanol and plasticizer into the saliva. The release of unpolymerized or soluble products could result in a stiffer, harder liner material over time.⁴ Soft lining materials can be divided into 2 main groups: a) Plasticized acrylics and b) Silicone elastomers. Both groups are commercially available in autopolymerizing and heat-curing forms. Plasticized acrylic lining materials are usually sup-

Corresponding Author:

Dr. Mahinder Singh Chauhan, Associate Professor, Department of Prosthodontics, Sharda School of Dental Sciences, Sharda University, Greater Noida, Uttar Pradesh, India; E-mail: drmahinder4@gmail.com

ISSN: 2231-2196 (Print)

ISSN: 0975-5241 (Online)

Received: 22.10.2020

Revised: 26.11.2020

Accepted: 19.12.2020

Published: 10.03.2021

plied in powder and liquid format with the powder consisting of a higher methacrylate polymer (usually polyethyl methacrylate) and a liquid consisting of a higher methacrylate monomer (eg:- ethyl, n-butyl). Also, there is a plasticizer (commonly a phthalate).⁵

Contemporary resilient liner materials can be divided into 2 groups: acrylic resin-based and silicone resin-based. Both groups are available in auto polymerized and heat-polymerized forms. Auto-polymerized resilient liner materials allow the clinician to reline a removable denture directly, intraorally. This method is faster than using heat-polymerized (laboratory-processed) systems. However, it is difficult to produce liner materials of the optimum thickness with the auto polymerized technique. The maximum thickness has been described as around 2.5 to 3 mm, which is required to offer good shock absorption.⁴

Acrylic resin-based resilient liner materials generally consist of methacrylate polymers and copolymers, accompanied by a liquid comprising methacrylate monomer and plasticizers (ethyl alcohol and/or phthalate). These materials endure two processes when immersed in water: (a) the leaching of plasticizers and other soluble materials into the water and (b) the absorption of water by the polymer. It has been suggested that the initial softness of the plasticized acrylic resins results from the plasticizer, which is also responsible for maintaining material softness. The plasticizer lowers the glass transition temperature of the polymer to a value below mouth temperature so that the modulus of elasticity of the resilient material is reduced to a satisfactory level. Silicone-based resilient liner materials are similar in composition to silicone-type impression materials (as they are dimethylsiloxane polymers). Polydimethyl siloxane is a viscous liquid that can be cross-linked to form an elastic rubber. No plasticizer is necessary to produce a softening effect with this material.⁴

There are several problems associated with the use of resilient denture liners is a bond failure between the liner and denture base. There is a possibility of bacterial growth and plaque and calculus formation with the failure of the bond. A variety of parameters affect the bond between the resilient lining materials and the denture base, including water absorption, surface primer use, and denture base composition.⁵⁻⁷

The purpose of this study was to assess the water sorption of acrylic resin-based auto-polymerized and heat-polymerized soft liners, and silicone-based auto-polymerized resilient line, and hardness of these soft liners throughout water storage for 1 day, 1 week, 1 month, 6 months and 1 year.

MATERIALS AND METHODS

This *in vitro* study was done in the Department of Prosthodontics and Crown and Bridge after obtaining approval from

institutional ethical committee. The study uses three common commercial resilient liner materials types based on chemical composition i.e., Self-cure silicone soft liner (UFI GEL P; VOCO; lot no 0929444) (Figure 1), self-cure acrylic soft liner (SOFT LINER; GC America; lot no.1107263) (Figure 1), and heat cure acrylic soft liner (GC-Super Soft; GC America; lot no.0803191) (Figure 1). Shore-A Durometer tester was used for testing hardness (Figure 1).

Hardness test

30 disc of 10 x 5mm in dimensions were made up of wax (Figure 2) were invested in dental stone using conventional denture flasks and dewaxing (Figure 2) was done conventionally. After the wax removal, the soft liner was packed after mixing and polymerized in the stone mould following the manufacturer's instructions.

For Super Soft (heat-cured acrylic soft liner), the monomer and polymer were mixed for 20-30 seconds in a plastic mixing cup and placed in the flasks. The flasks were placed under pressure for 30 to 40 minutes, and immersed in a water bath for 30 minutes at 62.4°C, followed by the slow increase of temperature by 30 minutes up to 100°C and the flask were kept in a water bath for 30 minutes. Then the flask was taken out of the water bath. Once the temperature of the flask came to the room temperature, the specimens were recovered and trimmed.^{8,9}

For Soft-line (auto polymerized acrylic soft liner), the polymer-monomer was mixed, placed in the flasks, and the flasks were placed under pressure for 15 minutes and specimens were recovered and trimmed.

UFI Gel-P (auto polymerized silicone soft liner), the monomer-polymer was mixed and placed in the flask, the flasks were placed under pressure for 30 minutes and specimens were recovered and trimmed.

Following polymerization, the samples were detached from the flask and trimmed using a sharp blade. Thirty specimens i.e. ten (10) specimens for each group was done. Each specimen was stored in water at 37°C for 1 day, 1 week, 1 month, 6 months and 1 year.

The Grouping of these specimens was as follows: (Figure 2) VOCO- UFI GEL: Auto-polymerized silicone liner (10 specimens).

GC- SOFT- LINER: Auto-polymerized acrylic liner (10 specimens).

GC- SUPER SOFT: Heat-polymerized acrylic liner (10 specimens).

Hardness test was determined using Shore-A Durometer tester and was recorded. Indentation hardness was performed with the durometer. This method is based on the indentation of the specified indenter forced into the material under specified

conditions.^{7,8} The Shore A durometer was held in a vertical position and the pressure of 1 kg was applied perpendicular to the surface of the specimens. The readings were obtained one second after firm contact was achieved.

Water Sorption Test

30 disc of 10 x 5mm in dimensions were made up of wax were invested in dental stone using conventional denture flasks and dewaxing was done conventionally. After the elimination of the wax, the resilient liner was mixed, trial packed and polymerized in the stone mould according to the manufacturer's instructions

After polymerization/processing, specimens were weighed immediately on an analytical balance (model 1712 MP8; Sartorius Corp, Edgewood, N.J.), placed in distilled water, and dark-stored at 37°C. After storage intervals of 1 day, 1 week, 1 month, 6 months, and 1 year, the specimens were removed. Overt moisture on the surface was dried quickly, and each specimen was weighed. Specimens were dried to bring the temperature up to room temperature. Water sorption was determined with the following formula: Wet weight- Dried weight/ dried weight x 100%.^{4,6}

RESULTS

The obtained data were tabulated and statistically analyzed using SPSS statistical software IBM version 20.0 and comparison of mean water sorption levels was compared using ANOVA with posthoc Games Howell test and mean hardness was compared using ANOVA with posthoc Tukey's test and p-value of <0.05 was considered statistically significant

The 2-way ANOVA test for water sorption of resilient liner materials for the five-time intervals are given in Table 1. The mean value for water sorption for self-cure, heat cure and silicone type was, 2.09, 0.08 and 2.04 respectively at one day and 2.12, 0.07 and 2.10mg respectively after one month, 2.16, 0.07, 2.10mg after 6 months and 2.18, 0.08, 2.10mg respectively after one year. The difference was statistically highly significant ($P<0.001$)

Our results indicate that the mean water sorption values of the self-polymerized resilient liner were significantly ($P<0.001$) greater than those of heat polymerized and silicone-based liners at one day to the one-year time period.

The water sorption data for all test products were associated with initially low sorption values that increased with the length of wet storage. There was a continuous rise in water sorption up to six months and later it raised marginally. For self-cure silicone also the rate of water sorption was similar to the self-cure acrylic.

Table 2 indicates the mean values of the hardness of three resilient liners for the 6-time intervals. The lowest hardness

values were seen in the specimens stored in the water for 24 hours, followed by the specimens stored for 1 week. In a heat cure acrylic group, the hardness values at 5% level ($p<0.05$) was significantly higher for all storage periods as compared to self-cure acrylic and self-cure silicone liner with different follow-ups. In self-cure acrylic, the hardness values for all storage periods at 5% level ($p<0.05$) was significantly smaller as compared to heat cure acrylic and self-cure silicone group with different follow-ups. Whereas in self-cure silicone, the hardness values at 5% level ($p<0.05$) was significantly higher as compared to self-cure acrylic but lower when compared to heat cure acrylic group for all storage periods with different follow-ups.

DISCUSSION

Because of the occurrence of a thin and relatively non-resilient mucosa or due to severe alveolar resorption some edentulous subjects may not bear a conventional hard denture base. In these situations, permanent soft liners are sometimes applied to the fitting surface of the denture employing temporary soft liners. Denture soft liners are used for edentulous patients for cushioning effect on functional forces.³

Acrylic-based soft liners are usually consisting of monomers and polymers. The composition of polymer (methacrylate polymers and copolymers), and monomer liquid containing methacrylate monomer and plasticizers (ethyl alcohol and/or phthalate). When immersed in water, these materials causes; the absorption of water by the polymer, leaching of plasticizers and other soluble materials into the water. It has been suggested that the initial softness of the plasticized acrylic resins results from the plasticizer, which is also responsible for maintaining material softness.⁶

The silicone-based soft liner has a comparable composition to silicone-based impression materials (as they are dimethyl-siloxane polymers). Polydimethyl siloxane forms an elastic rubber due to its vicious and cross-linking property. No plasticizer is necessary to produce a softening effect with this material.⁷

Soft liners can be either temporary soft liners (tissue conditioners) and permanent soft liners. Furthermore, permanent soft liners may be classified into 4 groups based on composition, as follows: (i) cold-cured silicone, (ii) heat-cured silicone, (iii) cold-cured acrylic resin and (iv) heat-cured acrylic resin. The acrylic temporary materials contain no initiator and no monomer and are comprised of non-cross-linked amorphous polymers. Both the silicone and acrylic permanent materials are comprised of cross-linked amorphous polymers.⁸ The adequate softness of resilient liner materials in the resilient denture liners and denture base material is required for long-term clinical use.⁹

High water absorption value has three important disadvantages. Firstly, the fitting of the appliance is crumbling as a swelling of the material takes place; secondly, swelling will put a further strain in the area of the bond among the two layers; and thirdly, it becomes unhygienic with the incorporation of bacteria and nutrient material in solution find their way into the resin.¹⁰ But the material should not be a water repellent or the thin film of saliva necessary in the retention of the denture may be deficient. It is known that lactic acid, even in weak solution, facilitates migration of the plasticizer from the vinyl resin. Dioctyl phthalate has been suggested as an alternative but results are little better.¹¹

Mese and Guzel assessed the consequence of storage duration on the tensile bond strength and hardness of resilient liners and concluded that lower bond strength values for resilient liners when immersed in water and higher hardness scores over time.⁴ These results are inconsistent with our results. Polyzoi and Frangou found significantly higher Shore A hardness values with heat-processed plasticized resin material compared to chairside material.⁵ These results are in agreement with our findings. Emmer Jr et al evaluated the bond strength of soft denture liners bonded to the denture base and found that greatest amount of stress needed for the failure of light-cure systems and low bond strength was observed when the adhesion was poor.¹² Garg and Shenoy observed that water sorption of the GC RELINE™ soft denture liner material was maximum in distilled water followed by 5.25% sodium hypochlorite.¹³ Jabbal and Datta similar to our findings observed, greater percentage solubility and absorption with acrylic-based soft liner, Viscogel, compared to silicone-based ones.¹⁴

Our study depicts that, hardness values for the heat cure acrylic product were consistently greater than those for the self-cure product and increased slightly over time. The results indicated that there were significant differences both in the hardness and water sorption values of resilient liner materials. The hardness of the self-cure recliners had lower hardness. Although there were differences in water sorption values for the heat cure acrylic and self-cure acrylic and self-cure silicone products. Increased processing temperatures were expected to result in a more complete polymerization reaction and thus a harder polymer network. It was anticipated that the higher conversion of the heat-processed material would lower its solubility. The results may have been influenced by material composition and chemistry as well as polymerization mode. The hardness values of all the soft liner materials assessed were greater with the enhanced duration of immersion.

The drawback of this study was the small sample size and the study was *in vitro* not *in vivo* one. Further *in vivo* studies are required to evaluate the efficacy of different soft liners on larger sample size.

CONCLUSION

The acrylic-based heat-polymerized (Super-soft) resilient liner had significantly higher hardness values than the auto polymerized acrylic and silicone. Our study depicts that, hardness values for the heat cure acrylic product were consistently greater than those for the self-cure product and increased slightly over time.

Conflict of interest: Nil

Source of funding: self

Acknowledgment: Nil

Authors contribution

1. Dr. Mahinder Singh Chauhan- Investigation
2. Dr. Roopsi Trivedi- Data collection
3. Dr. Prabhu Raj Singh- Investigation
4. Dr. Devendra Chopra- Manuscript writing
5. Dr. Debajyoti Sarkar- Analysis
6. Dr. Hemant Suresh Thodsare - Editing

REFERENCES

1. Duran RL, Powers JM, Craig RG. Viscoelastic and Dynamic Properties of Soft Liners and Tissue Conditioners. *J Dent Res* 1979;58(8):1801-1807.
2. Travaginni EA, Gibbons P, Craig RG, Ann Arbor, Mich. Resilient liners for dentures. *J Prosthet Dent* 1960;10(4):664-672.
3. Murata H, Taguchi N, Hamada T, Kawamura M, McCabe JF. Dynamic viscoelasticity of soft liners and masticatory function. *J Dent Res* 2002;81(2):123-128.
4. Mese A, Guzel G K. 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(2):153-159.
5. Polyzoi GL, Frangou MJ. Influence of Curing Method, Sealer, and Water Storage on the Hardness of a Soft Lining Material Over Time. *J Prosthodont* 2001;10(3):42-45.
6. Kawano F, Dootz ER, Koran A, Craig RG. Comparison of bond strength of six soft denture liners to denture base resin. *J Prosthet Dent* 1992;68(2):368-371.
7. Qudah S, Huggett R, Harrison A. The effect of thermocycling on the hardness of soft lining materials. *Quint Int* 1991;22(3):575-580.
8. Hekimoglu C, Anil N. The effect of accelerated ageing on the mechanical properties of soft denture lining materials. *J Oral Rehabil* 1999;26(4):745-748.
9. Rodrigues S, Shenoy V, Shetty T. Resilient Liners: A Review. *J Ind Prosthet Soc* 2013; 13(3):155-164.
10. Lammie GA, Storer R. A preliminary report on resilient denture plastics. *J Prosthet Dent* 1958;8(3):411-424.
11. Kutay O. Comparison of tensile and peel bond strength of resilient liners. *J Prosthet Dent*. 1994;71(1):525-531.
12. Emmer TJ Jr, Emmer TJ Sr, Vaidynathan J, Vaidynathan TK. Hardness of permanent soft denture liners bonded to the denture base. *J Prosthet Dent* 1995;74(4):595-601.

13. Garg A, Shenoy KK. A comparative evaluation of the 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 Ind Prosthodont Soc 2016;16(1):53–62.
14. Jabbal RS, Datta K. Comparative evaluation of water sorption and solubility of two auto polymerizing soft denture liners in distilled water and artificial saliva. Ind J Dent Sci 2016;8(4):208–212.

Table 1: Mean Values of Water Sorption of three resilient liners for the 5-time intervals in mg

Water sorption	Self		Group Heat		Silicone		p-value	Post-hoc test
	Mean	SD	Mean	SD	Mean	SD		
One day	2.09	.08	2.04	.05	1.97	.02	<0.001; Sig	Self, Heat> Silicone
One week	2.10	.08	2.05	.05	1.99	.02	<0.001; Sig	Self, Heat> Silicone
One month	2.12	.07	2.10	.05	2.04	.02	0.001; Sig	Self, Heat> Silicone
Six month	2.16	.07	2.10	.05	2.04	.02	<0.001; Sig	Self, Heat> Silicone
One year	2.18	.08	2.10	.05	2.06	.04	0.001; Sig	Self>Heat, silicone

ANOVA with posthoc Games Howell test

Table 2: Mean values of the hardness of three resilient liners for the 6-time intervals

Hardness	self		Group Heat		Silicone		p-value	Post-hoc test
	Mean	SD	Mean	SD	Mean	SD		
Initial values	8.40	1.96	36.30	1.95	28.50	2.76	<0.001; Sig	Heat>Silicone>Self
One day	8.45	1.95	37.60	2.07	28.50	2.76	<0.001; Sig	Heat>Silicone>Self
One week	8.85	1.97	39.90	2.28	28.16	1.67	<0.001; Sig	Heat>Silicone>Self
One month	10.05	1.91	40.30	2.31	28.48	3.20	<0.001; Sig	Heat>Silicone>Self
Six month	10.85	1.78	40.70	2.31	29.70	3.27	<0.001; Sig	Heat>Silicone>Self
One year	11.05	1.86	41.10	2.18	31.10	3.03	<0.001; Sig	Heat>Silicone>Self

*p<0.05 ANOVA with posthoc Tukey's test

Figure 1: Materials used.

Figure 2: Wax specimen, In the mould, Mould after dewaxing, Heat cure, Silicone, Self-cure, Disc fabrication.