Journal of Applied Sciences Research, 8(3): 1477-1483, 2012
ISSN 1819-544X
This is a refereed journal and all articles are professionally screened and reviewed

ORIGINAL ARTICLES

Viscoelastic properties of Thermo-Elastic resin reline with different ratios

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ABSTRACT

Aim: to evaluate and to compare the dynamic viscoelastic properties of thermo-elastic resin reline (Versacryl) to that of a silicon resilient liner (Molloplast B). **Materials & Methods:** Specimens for Molloplast B and Versacryl with three different softener/hardener monomer ratios were prepared. The dynamic viscoelastic analysis at a frequency of 1Hz at 37º C was carried out using a dynamic viscoelastometer. The shear storage (G′), loss (G″) moduli and loss tangent (tan δ) were obtained. These parameters were compared using ANOVA and Tukey tests. **Results:** There were significant differences between Molloplast B and the different Versacryl reline ratios for all measured parameters. The three tested ratios of Versacryl relines showed higher G′ and tan δ values than Molloplast B. **Conclusion:** The tested ratios of Versacryl relines had viscoelastic properties, while the Molloplast B demonstrated elastic properties. The different ratios of Versacryl reline showed different viscoelastic properties. Versacryl reline with 83% softener monomer and 17% hardener monomer produces the most desirable viscoelastic properties required clinically.

Key words: viscoelastic properties, denture liners, hard liner, thermoelastic resin reline, resilient liners, silicone liner.

Introduction

Resilient liners are frequently applied to the fitting surface of a complete denture to improve the fit and retention and relief patient's pain and discomfort (Fujii *et al*, 2002; kimoto *et al*, 2006 & kimoto *et al*, 2008). Because of their viscoelastic properties; they act as a cushion between the hard denture base and mucosa and distribute functional forces more evenly on the supporting structures (Usanmaz *et al*, 2002 and Elias & Henriques, 2007). Therefore, they are beneficial for patients suffering from severe alveolar bone resorption, atrophic mucosa, for dentures opposing natural teeth (Winkler, 1988; Lacoste- Ferre *et al*, 2006 and Taguchi, 2007) and when implant restorations are not feasible because of anatomic, systemic or economic reasons(Lacoste- Ferre *et al*, 2006 and Ancowtiz).

A variety of methods have been used to measure viscoelastic properties of resilient liners (Dootz *et al*, 1993; Murata *et al*, 1998 and Murauk *et al*, 2003). The dynamic mechanical analysis (DMA) is one of the accurate methods used to define these properties (Wagner, 1995b; Murata *et al*, 2002 and Hiroshi *et al*, 2008). In this method both the elastic and viscous responses of a sample is determined in one experiment as a function of temperature and loading frequency (Saber-Sheikh *et al* 1999 and Phenoxi *et al*, 2004). Several rheological measurements are obtained such as; complex dynamic shear modulus (G*), shear storage modulus (G′), shear loss modulus (G″) and loss tangent (tan δ). The storage modulus describes the stored and recovered elastic energy of the sample during one cycle, while the loss modulus represents the dissipated energy of the sample per cycle. Loss tangent (tan δ) is the ratio of the loss modulus and the storage modulus (G″/G′), which reflects the cushioning effect against the masticatory forces during function (Hiroshi *et al*, 2008).

Denture liners are of two types, hard denture resin relines and resilient denture liners. Resilient liners are classified into temporary and permanent liners (Hiroshi *et al*, 2008). Most of the available permanent resilient lining materials are made of silicone, methyl/ethyl methacrylate, polyphosphazine, fluoroelastomer, or polyurethane (Kawano *et al*, 1997 and Hiroshi *et al*, 1998). Silicone based-liners have been widely used as permanent resilient lining owing to their excellent elastic properties, low water absorption and durability (Pinto *et al*, 2002; Jin *et al*, 2003 and Erguna *et al*, 2007). However, they have several disadvantages such as low tear strength, insufficient bonding to polymethylmethacrylate (PMMA) denture base that necessitate the application of adhesives (Kanie *et al*, 2008) and low cushioning effect compared to acrylic (Hiroshi *et al*, 2008 and Muhanad *et al*, 2010) and fluoroelastomer liners (Hiroshi *et al*, 1998 and Murauk *et al*, 2003). Several studies

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have been carried out in an attempt to improve the properties of existing silicone materials and/or to develop new materials for use as permanent resilient liners (Kanie *et al*, 2009; Muhanad, 2010 and Zang *et al*, 2010).

A multipurpose thermo-elastic acrylic resin material called Versacryl was introduced in the last decade. It is available in heat and chemical cure types. Both types are heat-sensitive cross-linked acrylic resin liner which chemically bond to the acrylic denture base and it remains thermo-elastic after polymerization to allow better adaptation to the soft tissues. At the body temperature it has cushioning effect as claimed by the manufacturer. The rigidity of Versacryl is controlled by varying the proportions of the softener and hardener monomers, allowing a wide range of consistencies for various applications such as flexible denture flanges, tissue conditioning, or permanent relining material.

No information, however, is available on the dynamic viscoelastic properties of Versacryl used either as a tissue conditioning or as denture relining material. This study was therefore conducted to evaluate and compare the dynamic viscoelastic properties of Versacryl liner with three different softener/hardener monomer ratios, to that of silicone based liner (Molloplast B).

Materials and Methods

Table 1: The two material used in this study and their compositions: a multi-purpose thermo-elastic acrylic resin (Versacryl) and Molloplast B.

Material	Description	Composition	Manufacturer
A Multi-Purpose Thermo-Elastic Acrylic Powder & liquid	Heat cured permanent hard liner	1. Powder : PMMA 2. liquid monomers a. Softener: Plasticized methacrylate monomer (Dibutyl Phthalate, Dioctyl Phthalate, Methyl Methacrylate, n-Butyl Methacrylate, Ethylene Glycol Dimethacrylate and N,N-Dimethyl-P-Toluidine) b. Hardener: Methacrylate monomer (Methyl Methacrylate and Ethylene Glycol Dimethacrylate) 3. premixed monomer reline 83% Softener : 17% Hardener	Key stone industries USA
Molloplast B	Heat cured permanent soft liner	Silicone based permanent soft liner	Detax Karl Huber GmbH & Co., Karlsruhe, Germany)

Specimens preparation:

A total of 40 specimens were prepared, ten specimens of Molloplast B and thirty specimens of Versacryl reline. Versacryl specimens were further subdivided into three groups (n=10) using three different hardener/softener monomer ratios including; pre-mixed reline monomer liquid (100%) softener (with no hardener)-(83%) softener/(17%) hardener, and (50%) softener/(50%) hardener ratio. Specimens of each material (1mm thickness, 30 mm long and 10 mm wide) were prepared by packing materials at dough stage, into a prepared dental stone moulds (Kimberlit, Protechno, Spain); prepared by investing standardized metal blanks in a flask. Proportioning, mixing, and curing procedures were followed as recommended by the manufacturer of each product.

Dynamic Mechanical analysis:

Dynamic viscoelastic properties were measured using viscoelastometer (Anton Paar, MCR301 SN80218500, Austria, Europe). Specimens were set in a shearing jig and tested at a frequency of 1 Hz at 0.7% strain, and at temperature 37 $\pm 1^{o}$C (Murata *et al*, 2002). The shear storage modulus (G'), shear loss modulus (G'') and loss tangent ($\tan \delta$) were calculated.

Statistical analysis:

All statistical analyses were performed using SPSS software package (Statistical Package for Social Sciences, version 10, SPSS Inc, Chicago, IL, USA). Comparisons of data were made by one-way Analysis of Variance (ANOVA) with a Tukey's multiple comparisons test at $p<0.05$ level to establish significance of differences.

Results:

Results of dynamic viscoelastic behavior of the tested materials are shown in Figs. 1and 2. There were significant differences between the different Versacryl reline ratios and Molloplast B for all measured parameters.

It was evident that shear storage moduli (G′) and damping factors (tan δ) of the three Versacryl reline ratios were significantly higher than those of Molloplast B ($p<0.05$). Results also demonstrated that, as the softener percentage was decreased, there was a significant increase in (G′) and a significant decrease in (tan δ) ($p<0.05$).

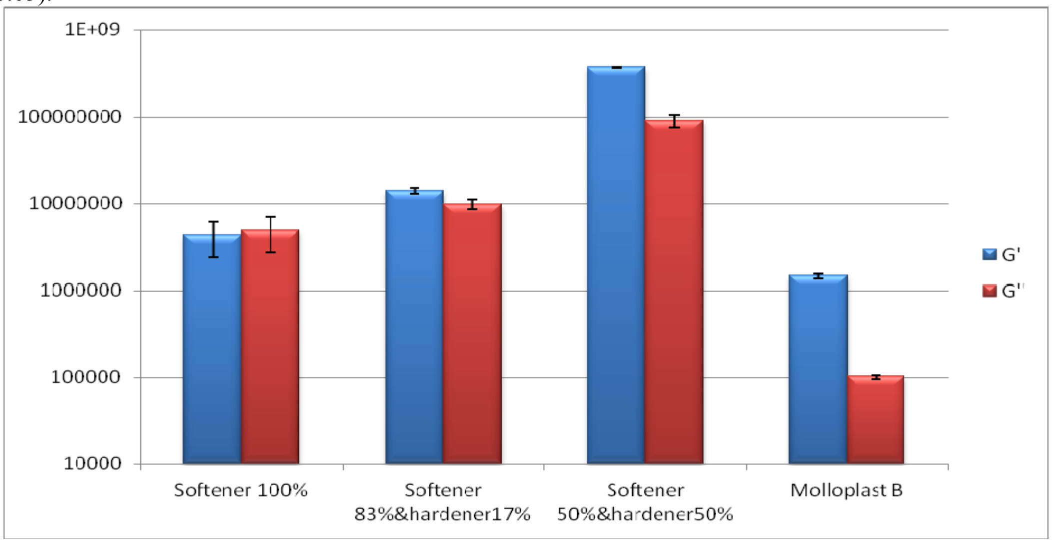

Fig. 1: Mean values (Pa) and standard deviations of (*G′*) and (*G″)* of the three tested Versacryl softener/ hardener ratios and Molloplast B.

Shear storage modulus (G′) of Versacryl reline with 50% softener/ 50% hardener ratio (3.66E+08 Pa) showed significantly the highest value ($p<0.05$), while that with 100% softener revealed the lowest value (4312500 Pa), and that of (83%) softener/ (17%) hardener was (13975000 Pa).

On the other hand, loss moduli (G") revealed insignificant differences between the two Versacryl reline ratios [(100%) softener and (83) % softener/(17%) hardener ratios] and Molloplast B. A significant difference of (G") value was found between Molloplast B and Versacryl reline ratio of (50%) softener/(50%) hardener ($p<0.05$). The loss modulus (G") of Versacryl reline with (50%) softener/(50%) hardener ratio had significantly the highest value (90850000 Pa) among the three ratios ($p<0.05$). While no statistically significant difference was detected between (G") value of reline with (83%) softener/ (17%) hardener ratio (9662500 Pa) and that of reline with 100% softener (4875000 Pa) ($p<0.05$).

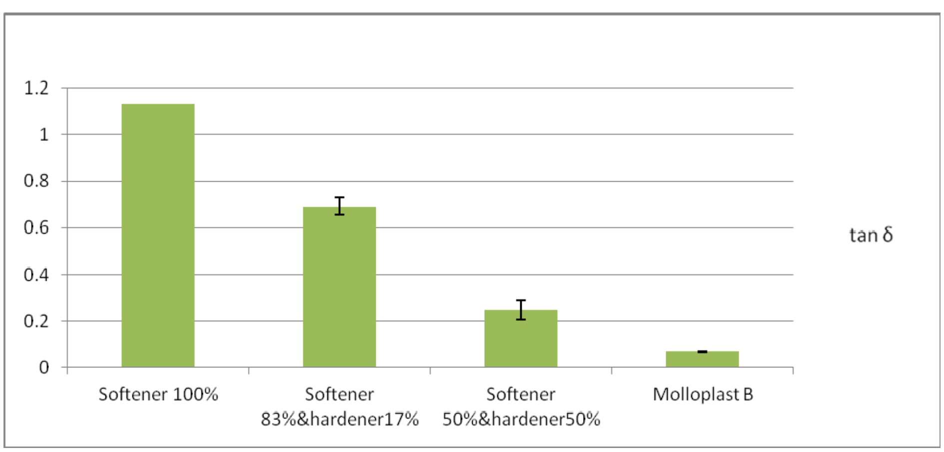

Fig. 2: Mean values and standard deviations of (tan δ) of the three tested Versacryl softener/ hardener ratios and Molloplast B.

As regards (tan δ); results indicated that reline with 100% softener showed the highest value (1.13000), followed by that of (83%) softener/(17%) hardener ratio (0.69075), then that of (50%) softener/(50%)hardener which had the lowest value (0.24800). The damping factor value of Molloplast B was (0.06958).

Discussion:

The use of resilient denture liners has improved the masticatory function, patient comfort and satisfaction as compared to hard denture bases. However, these liners suffer from several problems that necessitate periodic replacement (Polyzois *et al*, 2001; Mc Cab *et al*, 2002 and Pinto *et al*, 2002). Resilient liners should possess adequate physical and mechanical properties and bond well to PMMA of denture base and maintain this bond during the clinical service of the prosthesis. Silicone resilient liners are commonly used as permanent lining material attributed to their elasticity, chemical stability and relative durability compared to other acrylic resin based liners (Erguna, 2007 and Kasug *et al*, 2008).

Clinical performance and efficiency of resilient liners depends on their viscoelastic properties and durability. Viscoelastic behavior of liners determines their damping factor (i.e. cushioning effect) to absorb functional stress, allowing a more even pressure distribution and material resistance to deformation (Sorter, 1962 and Hiroshi *et al*, 2008). Ideal soft liners should exhibit elastic behavior against masticatory forces to transmit the energy required for mastication of foods and should behave viscously to distribute forces and absorb energy to produce the required cushioning effect (Murata *et al*, 2002).

Dynamic mechanical test was used to reproduce the stresses that liners are subjected to during function (Murata *et al*, 2002 and Hiroshi *et al*, 2008).

Three important rheological values were defined: storage modulus (G'); loss modulus (G"); and loss tangent (tanδ). The storage modulus (G') is a measure of the softness of a material and is related to the modulus of elasticity (Santawisuk *et al*, 2010).

loss modulus, (G"), defines dissipation of energy within a material that represent viscous response and damping factor or loss tangent (tan δ) indicates the ability of a material to dissipate mechanical energy through conversion into heat by molecular motion (Santawisuk *et al*, 2010).

A constant frequency of 1Hz was used in this study simulating the behavior at the masticatory rhythm, and a constant temperature at 37 ±1^{o}C was used representing the average temperature in oral environment for the soft lining material (Hiroshi *et al*, 2008 and Santawisuk *et al*, 2010).

In this study; the large differences in the viscoelastic properties among the Versacryl reline and Molloplast B were found and they are most likely due to differences in composition and structure (Murata *et al*, 2002). Analysis of the results revealed that Molloplast B exhibited the lowest values of G', G" and tan δ overall values that demonstrates elastic behavior while three Versacryl reline ratios showed viscoelastic properties (G', G" and tan δ).

Versacryl heat cure type was used in this study. It consists of two types of monomers instead of one as for conventional acrylic resin which are: softener and hardener monomers, the exact compositions were listed in table (1). Being heat sensitive, the Versacryl portion of a denture can be readjusted using warm water. Although, at room temperature the Versacryl reline is relatively hard but at body temperature it has a cushiony effect as was demonstrated in this study.

The storage modulus (G') is a measure of the softness of a material and is related to the modulus of elasticity (Wagner *et al*, 1995b). The softer the liner the more compliant and more appropriate the complete denture will be to the patients, especially those suffering from thin ridge and sore mucosa (Villar *et al*, 2003). Versacryl with the three different ratios has higher G' values i.e. They are stiffer and not soft as Molloplast B with lower G'.

Loss modulus G" is also a clinically important variable and it is relevant to the viscous response of the material to resist deformation under stresses. A resilient liner should exhibit a high value of G" at 1Hz to prevent flow of the material and to maintain permanent dimensional integrity of the lining (Murata *et al*, 2002). This is in consistence with results obtained in this study which indicate higher G'' for all Versacryl ratios.

The effect of softener percentage on the viscoelastic properties of Versacryl was also investigated in the study. Three proportions of softener monomers was evaluated including; 100% softener monomer A, premixed monomer reline (83% softener monomer A to 17% hardener monomer) and 50% softener monomer to 50% hardener monomer.

Softener monomer contains plasticizers which are responsible for a lowering the glass transition temperature and lowering the modulus of elasticity thereby producing less rigid material i.e. softer (lower G') at room temperature and increases damping effect (tan δ) (Pires -de- Souzaa, 2009). This clarifies the significant increase in G' and G'' and a significant reduction of tan δ; with decrease of softener monomer percentage. It could also be explained by the fact that sliding between the polymer chains would be more difficult with the decrease in the plasticizer content, hence; the material would behave in a stiffer fashion (Wagner *et al*, 1995 b).

As regards effect of hardener monomer percentage, it was found that increasing its percentage means increasing the effect of crosslinking agent (Ethylene Glycol Dimethacrylate) which connects the polymer chains and prevent the slididng movement of molecules (Pires -de- Souzaa, 2009) and consquently higher storage and loss moduli as detected in this study. In addition, cross linking agent lowers cushioning effect as was reported by Muruata *et al*, 2002. This effect is obvious with Versacyl reline ratio of 50%softener to 50% hardener comparable to the other two ratios.

In materials with high damping factor, much of the energy to deform a material is converted directly into heat (Murata *et al*, 2002). Therefore, tan δ is considered to reflect the cushioning effect required in the clinical situation. The tested ratios of Versacryl liners showed a significantly higher tan δ values than that of the silicone liner (molloplast B) with tan δ approaching zero. The results agree with the studies of (Wagner *et al*, 1995a and Murata *et al*, 2002) in a way that the silicones exhibited low damping factor. Such findings indicated that the ability of the Versacryl liners to absorb energy and reduce stress transmitted to the alveolar mucosa will be greater than that of the Molloplast B with lower tan δ value.

Murata *et al*, (2002) pointed out that improvement in masticatory function and patient satisfaction compared to hard denture base was found to be greater in dentures lined with materials having high tan δ and G' at 1Hz, than in those having low tan δ and high G', which in turn show improvement greater than that with materials having high tan δ and low G'.

Accordingly; Versacryl with 83% monomer softener and 17% monomer hardener; fulfills the previous criterion, by having high tan δ and G' compared to that of 50% monomer softener and 50% monomer hardener, having lower tan δ and higher G' which in turn show improvement greater than that of 100% softener having the higher tan δ and lower G'. In conclusion the use of Versacryl reline with 83% monomer softener and 17% monomer hardener is recommended as a relining material to improve the mastication for patient suffering from masticatory problems and masticatory pain could be prevented.

Further clinical investigations are required to determine the effect of water absorption and solubility on the viscoelastic properties of different softener /hardener ratios of Versacryl material; to help the evaluation of their durability in the oral cavity.

Conclusions:

Within the limitations of this study the followings were concluded:

1. The tested ratios of Versacryl relines had viscoelastic properties, while the Molloplast B demonstrated elastic properties.
2. The ability of the Versacryl liners to absorb energy and relieve stress is greater than that of the Molloplast B with lower tan δ value.
3. Versacryl reline with 83% softener monomer and 17% hardener monomer produces the most desirable viscoelastic properties required clinically: Thus it should be able to improve masticatory function and relieves patient pain and discomfort during mastication for complete denture wearers.

Conflict of Interest:

I hereby declared that there is no conflict of interest.

References

Ancowitz, S., 2004. Esthetic removable partial dentures. Gen Dent., 52: 453-459.

Dootz, E.R., A. Koran and R.G. Craig, 1993. Physical property comparison of 11 soft denture lining materials as a function of accelerated aging. J Prosth. Dent., 69(pt 1): 114-119.

Elias, C.N. and F.Q. Henriques, 2007. Effect of thermocycling on the tensile and shear bond strengths of three soft liners to a denure base resin. J Appl Oral Sci., 15(pt 1): 18-23.

Erguna, G. and I.N. Cekic, 2007. Color stability of silicone or acrylic denture liners: An in Vitro Investigation. Eur J Dent., 1: 144-151.

Fujii, K., H. Arikawa, T. Kanie, N. Shinohara and K. Inoue, 2002. Effect of photo-irradiation on hardness of soft lining materials for denture base. J Oral Rehabil., 29: 744-748.

Hiroshi, M., H. Taizo and S. Shinsuke, 2008. Relationship between viscoelastic properties of soft denture liners and clinical efficacy. Japanese Dent Sci Rev., 44(pt 2): 128-132.

Jagger, D.C. and A. Harrison, 1997. Complete dentures: the soft option: An update for general dental practice. Bri Dent J., 182: 313-317.

Jin, C., H. Nikawa, S. Makihira, T. Hamada, M. Furukawa and H. Murata, 2003. Changes in surface roughness and colour stability of soft denture lining materials caused by denture cleansers. J Oral Rehab., 30: 125-130.

Kanie, T., A. Kadokawa, H. Arikawa, K. Fujii and S. Ban, 2008. Effects of adding methacrylate monomers on viscosity and mechanical properties of experimental light-curing soft lining materials based on urethane (meth) acrylate oligomers. Dent Mater J., 27: 856-861.

Kanie, T., K. Tomita, M. Tokuda, H. Arikawa, K. Fujii and S. Ban, 2009. Mechanical properties and cytotoxicity of experimental soft lining materials based on urethane acrylate oligomers. DMJ., 28(pt 4): 501-506.

Kasuga, Y., N. Akiba, S. Minakuchi, T. Uchida, N. Matsushita, M. Hishimoto and I. Hayakawa, 2008. Development of soft denture lining materials containing fluorinated monomers. J Jpn Prosthodont Soc., 52: 183-188.

Kawano, F., A. Koran, A. Nuryanti and S. Inoue, 1997. Impact absorption of four processed soft denture liners as influenced by accelerated aging. Int J Prosthodont., 10: 55-60.

Kimoto, S., K. Kimoto, A. Gunji, Y. Kawai, H. Murakami, K. Tanaka, K. Syu, H. Aoki, M. Tani, M. Toyoda and K. Kobayashi, 2008. Effects of resilient denture liner in mandibular complete denture on the satisfaction ratings of patients at the first appointment following denture delivery. J Japan Prosthodontic society, 52(pt 2): 160-166.

Kimoto, S., S. Yamamoto, Y. Ohno, M. Shinomiya, K. Ogura and K. Kobayashi, 2006. Randomized controlled clinical trial for verifying the effect of silicone-based resilient denture liner on the masticatory function of complete denture wearers. Int J. Prosthodont, 19: 593-600.

Lacoste-Ferre, M.H., D.J. Dandurand, E. Dantras, M. Blandin and C. Lacabanne, 2006. Thermo-mechanical analysis of dental silicone polymers. J Mater Sci., 41: 7611-7616.

Mc Cabe, J.F., T.E. Carrick and H. Kamohara, 2002. Adhesive bond strength and compliance for denture soft lining materials. Biomaterials, 23: 1347-1352.

McMordie, R. and G.E. King, 1989. Evaluation of primers used for bonding silicone to denture base materials. J Prosthet Dent., 61: 636-639.

Hatamleh, M.M., C.J. Maryan, N. Silikas and D.C. Watts, 2010. Effect of net fiber reinforcement surface treatment on soft denture liner retention and longevity. J. Prosthod., 19: 258-262.

Murata, H., R.C. Haberham, T. Hamada and N. Taguchi, 1998. Setting and stress relaxation behavior of resilient denture liners. J Prosthet Dent., 80(pt 6): 714-722.

Murata, H., N. Taguchi, T. Hamada, M. Kawamura and J.F. McCabe, 2002. Dynamic viscoelasticity of soft liners and masticatory function. J Dent Res., 81: 123-128.

Murauk, G., H. Takahashi and I. Hayakawa, 2003. Effects of cyclic loading on viscoelastic properties of soft lining materials. DMJ., 22(pt 3): 251-261.

Phoenix, R.D., M.A. Mansueto, M.A. Ackerman and R.E. Jones, 2004. Evaluation of mechanical and thermal properties of commonly used denture base resins. J Prosth Dent., 13(1): 17-24.

Pinto, J.R., M.F. Mesquita, G.P. Henriques, N. Arruda and M.A. O´bilo, 2002. Effect of thermocycling on bond strength and elasticity of 4 long-term soft denture liners. J Prosthet Dent., 88(5): 516-521.

Pires-de-Souzaa, F.P., M.A. Vieiraa, L.F.R. Garcia and S. Consani, 2009. Impact and fracture resistance of an experimental acrylic polymer with elastomer in different proportions. Materials Research, 12(pt4): 415-418.

Polyzois, G.L. and M.J. Frangou, 2001. Influence of curing method, sealer, and water storage on the hardness of a soft lining material over time. J Prosthodont., 10: 42-45.

Saber-Sheikh, K., R.L. Clarke and M. Braden, 1999. Viscoelastic properties of some soft lining materials. (pt II) Ageing characteristics. Biomaterials, 20: 2055-2062.

Santawisuk, W., W. Kanchanavasita, C. Sirisinha and C. Harniattisai, 2010. Dynamic viscoelastic properties of experimental silicone soft lining materials. Dental Materials Journal, 29(4): 454-460.

Sato, Y., Y. Abe, H. Okane and K.Tsuga, 2000. Finite element analysis of stress relaxation in soft denture liner. J Oral Rehabi., 27: 660-663.

Storer, R., 1962. Resilient denture base materials. (Pt I). Introduction and laboratory evaluation. Br Dent J 113: 195-203.

Taguchi, N., H. Muratah, T. Hamada and G. Hong, 2001. Effect of viscoelastic properties of resilient denture liners on pressures under dentures. Journal of Oral Rehabilitation, 28: 1003-1008.

Taguchi, N., 2007. A clinical case report of complete dentures using resilient denture liners. J Oral Rehabil., 34(pt 11): 862-869.

Usanmaz, A., M.I. Alperlatifog, A. An, N. Akkas and M. Yetmez, 2002. Mechanical properties of soft liner–poly(methyl methacrylate)-based denture material. J Appl Polymer Sci., 85: 467-474.

Villar, A., 2003. Clinical evaluation of a new resilient denture liner: (Pt 1) compliance and color evaluation. J Prosthodont, 12: 82-89.

Wagner, W.C., F. Kawano, E.R. Dootz and A. Koran, 1995a. Dynamic viscoelastic properties of processed soft denture liners: (Pt I) initial properties. J Prosth, Dent., 73(5): 471-477.

Wagner, W.C., F. Kawano, E.R. Dootz and A. Koran, 1995b. Dynamic viscoelastic properties of processed soft denture liners: Part II--Effect of aging. J Prosth. Dent., 74(3): 299-304.

Winkler, S., editor 1988. Essentials of complete denture prosthodontics, 2nd ed. USA - PSG Publishing Co. pp: 427.

Zhang, H., J. Fang, Z. Hu, J. Ma, Y. Han and J. Bian, 2010. Effect of oxygen plasma treatment on the bonding of a soft liner to an acrylic resin denture material. DMJ., 29(4): 398-402.