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Resilient liners in prosthetic dentistry: An update

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Abstract
The unique abilities of resilient liner materials to control the distribution of stress over the denture bearing mucosa and to provide a cushioning effect to the cyclic forces of mastication make them suitable for a wide range of applications in the field of prosthetic dentistry. There are three categories of resilient liners – tissue conditioners, plasticized acrylics and silicon elastomers. Tissue conditioners are short term resilient liners used as temporary reline materials for immediate dentures and ill-fitting dentures to facilitate tissue healing without interfering with the use of the prosthesis. Plasticized acrylics and silicon elastomers are long term resilient liner materials recommended as preventive measures in patients with low tolerance threshold to load transmitted by the prosthesis. However, the effects of the oral environment on some of the desirable properties of these liner materials limit their durability. Recent researches have been focussed on enhancing their serviceable life and hence, clinical efficacy.

Keywords: Tissue conditioners, plasticized acrylics, silicon elastomers, viscoelasticity, micro-gap, micro-leakage

Introduction
Resilient liners are soft and elastic materials that have proved to be an excellent clinical adjunct in the management of patients with chronic denture soreness and have also found a wide range of applications in the field of maxillofacial prosthesis. Their effectiveness in handling such cases has been attributed to their inherent elasticity and viscoelastic property that enables them to control the distribution of stresses over the denture bearing mucosa and they also provide a cushioning effect to the cyclic forces of mastication. It has been very well established through several clinical trials that use of denture with resilient liners in edentulous patients results in greater comfort, markedly improved speech, reduced feelings of pain and soreness under the denture, greater ability to chew, better retention and stability, an increase in psychological comfort and longer denture wearing times [1, 2, 3].

Resilient liners can be short term resilient liners (Tissue conditioners) or long term resilient liners. Tissue conditioners are short term resilient liners used to treat denture soreness. They are used as temporary reline materials for ill-fitting dentures and immediate dentures to facilitate tissue healing without discarding the use of prosthesis and they are also for making functional impressions. This is in contrast with the long term resilient liners which are used to prevent denture soreness and are recommended as a preventive measure in edentulous patients with sharp and atrophied alveolar ridges, patients with thin atrophied mucosa exhibiting low tolerance to load transmitted by the prosthesis, patients who experience pain at nerve ending locations and in cases where denture exhibits poor retention causing recurrent sore spots under the denture [4].

Based on the composition, Long term resilient liners have been categorised into two groups --- Plasticized acrylics and Silicon elastomers. Both of these are commercially available in auto- as well heat-polymerized form. Long term resilient liners constitute those that should remain serviceable in the oral cavity for at least four weeks; in practice, however their use can extend up to several months and even years [5].

Composition & Structure
Tissue conditioners are auto-polymerised resins available as two components system - powder and liquid systems. The polymer powder generally consists of polyethyl methacrylate (PEM) with molecular weights ranging from 1.79×10^5 to 3.25×10^5 without any initiator and the liquid contains an ester based plasticizer and ethyl alcohol [6, 7]. Tissue conditioners contain no

monomers in the liquid and no initiator in the powder. The plasticizers commonly used are large molecular size aromatic esters (except dibutyl sebacate which is an aliphatic ester) such as dibutyl phthalate, benzyl benzoate, butyl benzyl phthalate [8]. There is absence of cross linkages between polymer chains and thus they can best described as non-cross-linked amorphous polymers. The large plasticizer molecule reduces the entanglement of polymer chains, thereby permitting individual chains to slip past one another. This slipping movement permits change in the shape of the soft liner and the set gel provides a cushioning effect for underlying tissue [9]. However the alcohol and the plasticizer leach out quickly and the material hardens within a considerably short time which varies from a few days to a week or two, and gradually loses its cushioning effect. Ideally a tissue conditioner should be replaced with a fresh mix every 2-3 days [10].

Long term resilient liners are commercially available as plasticized acrylics or silicon elastomers. Both can be either chemically cured (auto-polymerized) or heat cured. The auto-polymerized and heat-polymerized acrylic resilient liners are supplied as a powder and a liquid.

The powder generally consists of poly (ethyl methacrylate) or poly (butyl methacrylate) along with some peroxide initiator. The liquid of auto-polymerized acrylic liners contain 2-ethylhexyl methacrylate, tertiary amine and plasticizer while the liquid of heat-polymerized acrylic is a mixture of methyl methacrylate and plasticizer [11]. Heat cured silicon elastomers are supplied as a single paste system consisting of poly-dimethyl siloxane with terminal vinyl group through which cross linking occurs and benzoyl peroxide as initiator. Chemically cured silicon elastomers are supplied in the form of a two-paste cartridge - a base paste and a liquid catalyst. The base paste contains polymethyl-hydrosiloxane, as well as divinylpolysiloxane. The catalyst paste contains divinylpolysiloxane and a platinum salt. When the two pastes get mixed together, they undergo addition polymerization to yield the elastomer. Their softness is controlled by the degree of cross linking and hence unlike the case of acrylic based liners, plasticizers are not required to produce the softening effect. Addition of filler materials is also required to improve the mechanical properties of these materials as the mechanical properties of silicon elastomeric materials have been found to be insufficient for most of the prosthetic applications [5].

Properties, clinical implications and limitations

The desirable effects of resilient liner materials results from their ability to evenly distribute and absorb the functional forces during mastication by dint of their viscoelastic behaviour. In cases of unfavourable foundation areas (sharp/uneven/irregular alveolar ridge anatomy), the denture fails to fit and sit firmly on the foundation. Under masticatory load application, such dentures moves and tilts upon the foundation and thus beneath the denture, the area of support become small. Consequently, the pressure exceeds several folds greater than the average pain threshold of the alveolar mucosa and the patient complains of soreness and discomfort. Elastic deformation of the lining material beneath the denture base under masticatory load increases the contact surface beneath the denture resulting in more even pressure distribution and pain reduction.

Viscoelasticity is the property of a material by virtue of which it exhibits both elastic and viscous behaviour i.e. to say, the application of stress causes elastic deformation in it if stress is quickly removed but it causes a plastic deformation if it is sustained for a prolonged period. Several tests have been employed to investigate the viscoelastic properties of the the liner materials. However, it is to be understood that in clinical situations, the denture liners are exposed to both a rapidly applied forces caused by mastication or swallowing and to a more long term force caused by functional pressure or changes in the oral supporting tissues [12]. Also given the fact that the elastic recovery time for liner materials differ (for e.g. the elastic recovery time for silicone liner materials and acrylic soft liner materials are 1-2 sec and 30 secs respectively) [12]; for a test to be considered of clinical relevance it becomes necessary to measure the viscoelastic properties over a wide range of frequencies in order to allow correct predictions of viscoelastic behaviour under these clinical situations [12]. The dynamic mechanical test using viscoelastometer based on the principle of a non-resonance forced vibration fulfil this criteria. In the dynamic mechanical test, three rheological parameters are generally used for evaluation of the dynamic viscoelasticity of materials- (i)storage modulus (E') which describes elasticity of materials (ii) loss modulus (E") describes viscosity (iii) loss tangent (tan δ) is the ratio of the loss modulus and the storage modulus (E'/E") [11]

Murata *et al.* [14] found that acrylic lining materials which exhibit higher values of loss tangent (δ) and storage modulus (E') provide greater improvement in masticatory function compared to silicon liners which exhibit lower values of loss tangent (δ) and higher value of storage modulus (E'). Tissue conditioners which have higher loss tangent values but lower storage modulus provide lesser improvement compared to acrylic or silicon liners.

Plasticizers are added to acrylic based liner to impart flexibility and desired softness, but they are not bound within the resin mass. Therefore they may be leached out of the resin mass resulting in the loss of desirable mechanical properties of these materials. The softness of silicon based liners is controlled by the degree of cross linkages between the polymer chains and the presence of fillers. Thus, quite unlike the case of acrylic based liners, they do not require the presence of leachable plasticizers to produce the desired softening effect. Consequently, they are capable of retaining their desired properties for prolonged periods and are considered to be more durable.

However, an inherent limitation of silicone resilient liners is their inability to form durable bond with the denture base material. Polymethyl methacrylate (PMMA) denture base resin and silicon based lining materials have different molecular structures and cannot be chemically bonded and thus, the bonding between them relies completely on the use of an interfacial adhesive [15]. Failure of adhesion of these liners to the denture base lead to the existence of a micro-gap at resin base- soft liner interface. Such micro-gap may serve as a potential source for micro-leakage culminating in the de-bonding of liner from denture base [16]. To overcome this problem, the use of a suitable solvent based primer is recommended. Sarac *et al.* [17] in their study concluded that the surface treatment of the denture base resin with methyl methacrylate monomer prior to adhesive application caused swelling of the denture base surface resulting in better penetration of the adhesive into the denture base and hence more effectively reduced micro leakage compared to the use of the adhesive alone. Results from another study also showed that treating a denture base acrylic resin surface with chemical etchants (acetone, methyl methacrylate, methylene chloride) prior to ad methacrylate hesive application significantly reduced the microleakage and increased the bond strength when using silicone-based resilient liners, but these chemical treatments did reduce the flexural strength of the acrylic resin when compared to the control group [18].

Microbial colonization of the denture lining material poses a significant challenge. The conditions prevailing in the oral cavity under the denture base i.e. high humidity, warm temperature, inaccessibility to self-cleansing action of action promote the growth of micro-organisms. Micro-organisms initially adhere to surface of the liner material and later they also invade into the structure of the materials. The latter phenomenon in particular reduces the effectiveness of conventional denture cleansers to restrict their growth. All this may predispose the patient to infection and denture-induced stomatitis. Studies have shown that rougher surface of the resilient liners favours the adhesion of micro-organisms and allow fungal growth [19, 20]. Kang *et al.* [21] reported that acrylic based soft liners exhibited greater *Candida* adhesion compared to silicon liners and attributed this result to the base components and the hydrophilicity of the materials. Also heat cured silicon liners exhibited significantly less yeast adhesion than RTV silicon linings [22]. The chemical composition of the room temperature polymerized resilient liners and the difference in surface energies or higher hydrophilicity could be the reasons for this condition. Bulard *et al.* [27] in his study on the colonization of *C. Albicans* and penetration of long term resilient liners noted a high degree of colonization in the region of resin denture base – silicon soft liner interface which may be attributed to the existence of micro-gap in this region due absence of durable and ineffective bond between the denture base and the silicon soft liner. This could be a potential cause for the de-bonding of silicon soft liners in the oral cavity.

In the moist environment of the oral cavity, the resilient liners exhibit water sorption, the degree of which depends upon the hydrophilicity of the matrix and the presence of leachable plasticizers or other soluble substances [5]. This phenomenon may manifest as alteration in mechanical properties of the liners (e.g. loss of viscoelastic behaviour), change in dimensions, microbial growth, discoloration, etc. It also reduces the bond strength to denture base resins by direct damage at the bond site due to swelling and stress build up at the bond interface and/or by changing the visco-elastic properties of the lining material rendering the liner relatively stiff and less yielding, thus transmitting the external load to the bond site [24]. Silicone elastomers are hydrophobic by virtue and they do not contain leachable plasticizers, so water sorption is significantly lower which accounts for their greater dimensional stability, better retention of elastic properties, more color stability and hence prolonged durability. However, a potential drawback of the hydrophobicity of silicon-based liners could be absence of good affinity to the supporting tissues.

Recent advancements and research trends

Plasticized acrylics which exhibit greater values of storage modulus E', loss modulus E" and loss tangent values E"/E' as confirmed by dynamic mechanical analysis (DMA) techniques have greater cushioning effect than silicone elastomers. This has been reflected in a study by Murata *et al.* [14] in which the masticatory functions of ten subjects were evaluated in terms of maximum bite forces, chewing time and frequencies of 2 food samples, and by the use of visual analogue scales. The improvement in masticatory function was found to be in the order: acrylic permanent soft liner > silicone permanent soft liner > tissue conditioner > hard resin. Thus, plasticized acrylics may best meet the requirements of a resilient denture liner but they significantly lag behind silicon elastomers in terms of durability due to the presence of leachable plasticizers. Studies have been directed towards increasing the durability of resilient liners by application of surface sealants to prevent the leaching out of plasticizers and other soluble constituents from the lining material. They also prevent the absorption of salivary inorganic salts, which may be a contributing factor in the hardening and loss of serviceability of the liner materials. Mante *et al.* [25] in their study found that the application of surface sealants can prevent an increase in the hardness value of the acrylic-based liner materials in service for extended periods and hence can contribute to their durability.

Microbial colonization of the resilient liner material still remains an unresolved issue and has also been postulated to be a potential cause of de-bonding of silicon liners from the denture base. Incorporation of anti-fungal agents such as nystatin have been proposed but they are effective only for short periods [26]. Similar issues arise with incorporation of nano-silver particles into liner materials. Silver ions released into the environment decreased overtime which could reduce their anti-microbial properties [27]. Also nano-silver particles may cause alteration of mechanical properties and discoloration of the liner material [28]. The use of white ceramic micro- or nanofillers with antimicrobial properties appears to be a more appropriate solution to this solution but more research works are warranted in this regard [5].

In attempts to improve the properties, microbial resistance and durability, newer lining materials have also been introduced. These include a polyisoprene-based light curing lining material (Clearfit LC) and a polyphosphazene-based liner (Novus). Hayakawa *et al.* [29] in their study compared some of the clinically relevant properties of Clearfit LC with four commercial products – two plasticized acrylics (Super-soft, Soften) and two silicones (Molloplast B, Sofreliner). They found that the polyisoprene-based material exhibit low water sorption and solubility, moderate softness, high staining resistance and satisfactory shear bond strengths to the denture base resins. It also provide clinicians sufficient working time due to light curing properties and thus can serve as attractive alternative as a lining material.

The desirable properties of polyphosphazene-based liner materials include excellent shock absorption, durability due to lack of plasticizers, resistance to fungal growth [30, 31, 32], low water sorption hence more dimensional stability, color stability, decreased porosity hence low staining and presence of odour [32]. Also, it is radiopaque and can be identified if any parts or pieces gets accidentally ingested or inhaled by the patient[33]. This becomes of particular significance in dealing with patients with neuro-muscular disabilities and patients of maxilla-facial prosthetic rehabilitation.

Conclusions

Resilient liners find a wide range of applications in the field of prosthetic dentistry due to their inherent viscoelastic property which enable them to cushion and evenly distribute the masticatory load beneath the denture. They are used to treat mucosal soreness resulting from ill–fitting prosthesis (tissue conditioners) and their use is also recommended as a preventive measure in patients who are likely to develop mucosal soreness with the regular use of the prosthesis. However, the effects of the oral environment on their some of their desirable properties limit their clinical efficacy.

Microbial colonization of the denture liners continues to be an unresolved issue with the use of the soft liners. The growth and penetration of microbial biota particularly in the region of denture base-soft liner interface has been ascertained as a significant factor contributing to the de-bonding of silicon liner from the denture base. Attempts have been made to incorporate anti-fungal agents like nystatin, nano-silver particles into the liner materials but their effects have been found to be short lasting.

A higher value of loss tangent (tanδ) reflects the viscoelastic behaviour of liner material. Lower value of loss tangent reflects its elastic behaviour. While viscoelasticity of a liner material defines its ability to impart a cushioning effect to the masticatory load, its elastic behaviour determine its ability to increase the contact area beneath the denture base by elastic deformation under masticatory load and thus providing a more even pressure distribution. Acrylic based resilient liners which exhibit greater viscoelastic behaviour have been found superior to silicon based resilient liners (which are found to exhibit more of elastic behaviour) in terms of providing greater degree of stress relief and increased patient comfort but they lag behind silicon materials in terms of durability. They contain leachable plasticizers that may dissolve out resulting in loss of their desirable properties. In addition, they exhibit greater water sorption, dimensional changes and discoloration which limits their serviceable life. Thus, liner materials exhibiting both desirable traits i.e. optimum viscoelasticity and good durability is yet to be developed and more research works are warranted in this direction to develop an ideal resilient liner.

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