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"Bond strength of 3d printed acrylic resin with silicone soft liner after ethyl acetate surface treatment (A Review of Literature)"

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Abstract:

This literature review emphasizes the impact of ethyl acetate organic solvent as surface treatment agent for 3-dimentional (3D) printed polymethyl methacrylate denture base and silicone soft liner on enhancing the strength of bonding of these materials. Over time, Denture soft liner materials have appeared as important components in prosthodontics, offering enhanced comfort, tissue adaptation for denture wearers and restore the inflamed and distorted mucosa. It is commonly agreed that the main drawback is debonding of the lining material from the 3D printed denture base. Therefore, there is a need for enhancing the strength of bonding of these materials.

Keywords Ethyl acetate, 3-dimentional, Polymethyl methacrylate, Silicone.

Introduction:

The polymer polymethyl methacrylate (PMMA) is the material most frequently used to create traditional complete dentures. The material's relative simplicity in manufacturing, repair, biocompatibility, and aesthetic qualities have enhanced patient acceptance. PMMA is widely utilized because of its exceptional physical and mechanical qualities in the manufacturing of removable dentures (Alqutaibi et al., 2023).

Polymer polymethyl methacrylate has many advantages but also has a number of drawbacks to this material, including a shrinkage, ability to become colonized by bacteria from the oral environment, insufficient radiopacity, allergy primarily brought on by the leaching of the monomer, a gradual deterioration of the mechanical properties, and resistance to wear in saliva was low. These flaws have prompted the development of novel materials and production processes like additive and subtractive techniques (Gautam et al., 2012) (Akin et al., 2015).

Digital denture bases can be fabricated by two main digital processes; the subtractive and the additive (Schweigera et al., 2018). Additive manufacturing, commonly referred to as 3-dimensional printing or fast prototyping, which was layer-by-layer object fabrication (Anadioti et al., 2018).

Comparing digital dentures to traditional processed dentures, there are a number of benefits. Firstly, fewer visits of patients, which is advantageous and convenient for elderly patients who may find it difficult to drive repeatedly to the dentist's office. (Bilgin et al., 2016; Srinivasan et al., 2019).

Relining is the procedure used for resurfacing of the intaglio part of a removable partial or complete denture with new base material, thus creating an accurate adaptation to the denture denture-bearing tissue (GPT, 2017). Relining materials for denture are used to modify dentures to prevent excessive residual bone resorption, treat xerostomia, treat bony undercuts, thin and non-resilient mucosal tissue, and prevent persistent discomfort in patients (Surapaneni et al., 2013).

The clinical efficacy of soft-lining materials is well documented, although their usage is frequently discouraged due to their poor physical characteristics like the most critical problem is debonding of the lining material from the denture base, which can lead to bacterial growth and faster soft-liner deterioration (Xiaoqing et al., 2015). Due to bacterial buildup, discoloration, impaired hygiene of mouth, and detachment of the reline material, the bond-strength among the denture-relines and the base of the denture is essential (Fatemi et al., 2019) (Choi et al., 2018).

There are numerous ways to prevent the relining of denture from coming away from the base, but in order for these ways to work, there needs to be a strong adhesive bond between these surfaces, which may be impacted by the denture-base material (Awad et al., 2021), the surface treatments and physical-mechanical treatments improve adhesiveness (Kreve and Dos Reis, 2019).

Among the chemical surface treatments are organic solvents, such as ethyl acetate (Cavalcanti et al., 2014).

The International Agency for Research on Cancer (IARC) does not classify ethyl acetate as a carcinogen, so it was chosen as a harmless surface preparation agent (Shimizu et al., 2008).

Acrylic denture base material:

The most popular denture base material right now is acrylic resin. They have a number of benefits, including a straightforward laboratory methodology, the need for no special equipment, acceptable aesthetics, acceptable strength, and a reasonable cost. Acrylic resin denture bases are the most popular choice due to their ease of processing and aesthetic appeal. They reproduce surface details accurately and have a high level of strength, stiffness, hardness, and toughness. They exhibit good dimensional stability, are resistant to oral fluid absorption, have a long shelf life, and are free of toxicity, odor, and taste (Van Noort, 2014).

However, there are a number of drawbacks to this material, including a shrinkage, ability to become colonized by bacteria from the oral environment, insufficient radiopacity, allergy primarily brought on by the leaching of the monomer, a gradual deterioration of the mechanical properties, and resistance to wear in saliva was low (Chuchulska et al., 2017).

1. Heat-polymerizable acrylic resin:

The vast majority of denture bases is manufactured using heat-activated materials. A water bath or microwave oven can be used to generate the thermal energy required for polymerization of these materials. The powder is composed of poly methyl-methacrylate spheres that have been pre polymerized and a trace of benzoyl peroxide, referred to as the initiator, which initiates the polymerization process. The liquid is primarily composed of monomer methyl methacrylate with trace amounts of hydroquinone. Hydroquinone is added as a polymerization inhibitor, preventing the

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liquid from setting or polymerizing during storage. Additionally, inhibitors delay the curing process, extending the amount of time available for work. Additionally, the liquid may contain a crosslinking agent. In polymethyl methacrylate denture base resins, glycol di-methacrylate is frequently employed as a cross-linking agent (Anusavice et al., 2013).

2. Auto-polymerizable acrylic resin:

Chemical activation is most frequently achieved by adding a tertiary amine to the denture base liquid, such as dimethyl-para-toluidine. The tertiary amine decomposes benzoyl peroxide upon mixing the powder and liquid components. As a result of this reaction, free radicals are generated and polymerization begins. Polymerization proceeds similarly to how heat activated systems do (Anusavice et al., 2013).

3. Thermoplastic acrylic resin:

Acrylic resin material is well identified as polymethyl methacrylate or PMMA acrylic resin has a wide range of applications in dental practice for many years in the construction of temporary crowns and for being thermally polymerized as baseplate material for partial and complete dental prostheses. Thermally polymerized PMMA is highly porous with high water absorbing ability, dimensional instability and high content of residual monomer, these properties resulted in several drawbacks accompanying thermally polymerized acrylic when compared to the thermoplastic material (Negrutiu et al., 2005).

The absence of residual monomer is the primary distinction between thermoplastic-acrylic and polymethylmethacrylate conventional-acrylic resins. Thermoplastic are stable in stomach acids, alcohol, water, simple aromatic hydrocarbons, and saliva. (Chuchulska et al., 2017).

4. Light-activated acrylic resin:

A light-activated technology has become available in recent years and is being used in a variety of prosthetic applications. This substance is made of an acrylic copolymer, a microfine silica filler, and a urethane di-methacrylate matrix. It is available as a pre-mixed sheet or rope (Anusavice et al., 2013).

A base is made by fitting the substance to a mold and curing it in a chamber of light at a wavelength of 400–500 nm. Flasks, wax, boiling tanks, packaging presses, and heat processing equipment needed for traditional denture production were no longer necessary. (O’Brien, 2008).

5. Microwave cured acrylic resin:

It has been proposed to use microwaves to start the polymerization of this resin. The approach was improved in 1983 when a unique glass fiber-reinforced plastic flask made for use in a microwave oven was created. Typically, the liquid monomer is altered to regulate the monomer's boiling point in the course of a quick curing cycle lasting 3 minutes at 500–600 W/cycle. Due to the numerous quick intermolecular collisions that occur during this process, heat is produced quickly inside the monomer. The monomer content decreases rising levels of polymerization and the remainder monomer is transformed into a polymer as more energy is absorbed (Zarb et al., 2013).

6. Subtractive or milled CAD/CAM acrylic:

Modern technological advances enable the use of various computer aided design/computer aided manufacture (CAD/CAM) techniques, including milling and fast prototyping, for the construction of removable dentures. These breakthroughs have been ongoing over a number of years (Bilgin et al., 2016).

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Because the denture is milled from a prepolymerized disk acrylic this preventing further curing shrinkage, milled denture-bases have less deviation in volume (Goodacre et al., 2016).

A thinner base covering the palate can be designed because of the prepolymerized acrylic better physical qualities (Koike,2011). The milled denture appears to have better physical characteristics, the resin is more hydrophilic, for instance (wettable) (Qanber and Hamad, 2021), has fewer residual monomers (Ayman, 2017; Steinmassl, 2017). In addition, the milled denture is denser than heat-activated traditional denture base (Ali, 2008; Ayman, 2017).

Kanazawa et al. (2011) used subtractive manufacturing in an effort to enhance and accelerate the digital denture manufacture process. A 3D-CAD design program was used to create the virtual denture. The transparent denture bases were then milled using a milling machine with recessed areas into which denture teeth were subsequently hand glued.

Since the PMMA used for milling dentures are polymerized by injection under high- pressure and temperature, a procedure that encourages the development of longer polymer-chains that result in maximum monomer conversion, minimum porosity, and reduced residual monomer values. CAD/CAM systems offer a number of clinical advantages (Murakami, 2013; Kattadiyil, 2015; Mohammed and Mahmood, 2021). It is most likely a result of the processing technique using high temperature and pressure, which led to a low concentration of monomer residue.

The primary drawback of the subtractive method is waste because a sizable percentage of the blank is left unused and thrown away during this procedure (Nakayama et al., 2016).

7. Additive or 3D printing acrylic resin:

Additive manufacturing, commonly referred to as rapid prototyping or three-dimensional (3D) printing, includes processes that create products layer by layer (Anadioti et al., 2018).

Digital denture bases have recently been made using additive manufacturing techniques. The capability of creating objects, regardless of its dimensional complexity or quantity, is one advantage of additive manufacturing over milling. Additionally, additive manufacturing creates less waste than milling and can recreate precise features (Awad et al., 2021).

3D solid object creation via printing is an alternative to the conventional product manufacturing procedure. In other words, additive manufacturing is the same as 3D printing and permits the construction of physical 3D models of objects utilizing a series of additive or layered development, where layers are laid down in succession to build a complete 3D object (Lindemann, 2017).

Additive manufacturing consumes less material and produces the fine details, undercuts, and voids that are difficult to reproduce with subtractive manufacturing. (Lindemann, 2017).

3-dimensional Printed digital denture

This new technology originating from the area of rapid prototyping, the phrase 3D printing is typically used to refer to a manufacturing process that creates objects by adding one-layer at a time. This technique has been modified to meet the demands of dental technology and is more accurately known as additive-manufacturing and fast prototyping (Prajapati, 2020).

1. Advantages of digital dentures:

Comparing digital dentures to traditional processed dentures, there are a number of benefits. Firstly, fewer visits of patients, which is advantageous and convenient for elderly patients who may find it difficult to drive repeatedly to the dentist’s office (Bilgin et al., 2016; Srinivasan et al., 2018).

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Complete denture therapy is more affordable due to the shorter amount of clinical chair time needed for manufacture (Srinivasan et al., 2018). Furthermore, a copy denture or a surgical-template can be made in the future using the repository of digital data (Bilgin et al., 2016). Replacement dentures will also have the same external base shape and tooth placements, making it easier for patients to get used to the new dentures. The occlusion of CADCAM produced dentures will require less occlusal modification with monolithic milled full dentures and accurate interocclusal recordings (Bilgin et al., 2016).

Completion of impressions, interocclusal records, and tooth selection in the same appointment. Dentures are then created utilizing CAD/CAM technology and placed in the second visit. The denture base is milled from blanks first, and then the teeth are attached using a special glue. Due to the lack of a polymerization process, they not only require less chair-time and appointments but also show less shrinkage. Because records are stored digitally, it is simple to make duplicate dentures (Manappallil, 2015).

When compared to traditional complete dentures, CAD/CAM dentures are more quickly produced, which benefits the dental technician. They need fewer lab processes and don't need gypsum casts or articulation (Bilgin et al., 2016).

Cast analysis and denture teeth set-up can be completed more quickly because to the CAD/CAM dentures' digital design software. Additionally, the lab technician can give the clinician a complete denture that fits better and is of higher quality. Last but not least, unlike the traditional pack-press method, the technician does not have to mix acrylic resin and is therefore not exposed to monomer (Srinivasan et al., 2019).

2. Disadvantages of digital dentures:

When compared to complete dentures that have been manufactured conventionally, digital dentures have a number of drawbacks. A clinical remount process will frequently be necessary to balance the denture teeth when manufacturer's denture teeth are manually glued to milled denture bases to get balanced occlusion (Baba et al., 2021).

Another drawback of digital dentures for clinicians is that it may take more time and effort to resolve design-related concerns when communicating with the dental laboratory (Baba et al., 2021). It's important to consider how CAD/CAM affects the environment since milling processes create resin particles that add to the environment's plastic pollution. Similarly, there is no biodegradability in silicone impression materials. Finally, Dentures need to be sent and packaged logistically, which may involve going through international customs (Baba et al., 2021).

3. Computer/aided designing (CAD) of digital denture:

It is a computer unit with a software package for visualization of the scanned data, planning and designing dental restorations on a computer screen. Software's collect data in the Standard Transformation Language (STL) or so-called Standard Tessellation Language format. It is possible to design a variety of dental restorations such as veneers, inlays, onlays, individual crowns, bridge copings, partial denture frameworks and complete dentures. When the restoration design is finished, the CAD software converts the virtual model into a precise set of instructions that are then used to operate the CAM unit to create the designed restoration (Beuer et al., 2008; Bilkhair, 2013).

The software based on their ability to share digital data, CAD/CAM systems can be classified as either closed or open systems. In the closed system, all the steps of digitizing, designing and manufacturing are integrated in the unique system with no interchangeability with any components manufactured by another company. However, the new trends are directed towards the open systems, which allow the adoption of the original digital data by CAD software and CAM devices from different companies (Ting-Shu and Jian, 2015; Alghazzawi, 2016).

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4. Computer/aided manufacturing (CAM) of digital denture:

Computer/aided manufacturing is the final stage. The CAM technique can be categorized into two categories based on the method employed: milling or 3D printing (Parasher, 2014).

Additive manufacturing, commonly referred to as 3-dimensional printing or fast prototyping, which was layer-by-layer object fabrication (Anadioti et al., 2018). Below is a list of the several types of printing technology (Bhalerao, 2018):

I. **Fused deposition modelling (FDM):**

Scott Crump, the founder of Stratasys Ltd., initially invented and applied FDM technology in 1980. FDM uses heated thermoplastic filament that is extruded to create parts layer by layer. It is perfect for creating strong parts with intricate geometries in almost any size and form (Torabi, 2015).

Additionally, FDM produces parts and prototypes with exceptional thermal, chemical, and strength-to-weight ratios. This technique has many advantages, including design freedom and the ability to construct complicated parts using the same tried-and-true thermoplastics used in traditional production (Bhalerao, 2018).

II. **Digital light processing (DLP):**

Another 3-D printing technique that is quite similar to stereolithography is DLP. It was developed in 1987 by Texas Instruments' Larry Hornbeck and quickly rose to prominence in the projector industry (Torabi, 2015). In order for the DLP to function, a vat of liquid resin must be subjected to safelight conditions from a DLP projector. The 3D model's image is projected onto the liquid-resin using the DLP projector, such as shown in (Figure 1), as the plate of printer descends and the liquid-resin polymer is exposed to light once more, the resin polymer became hard.

The procedure is continued until the 3D model is finished, at which point the liquid in the vat is removed to expose the solidified model. A quicker approach that produces items with a better resolution is the DLP printer (Bhalerao, 2018).

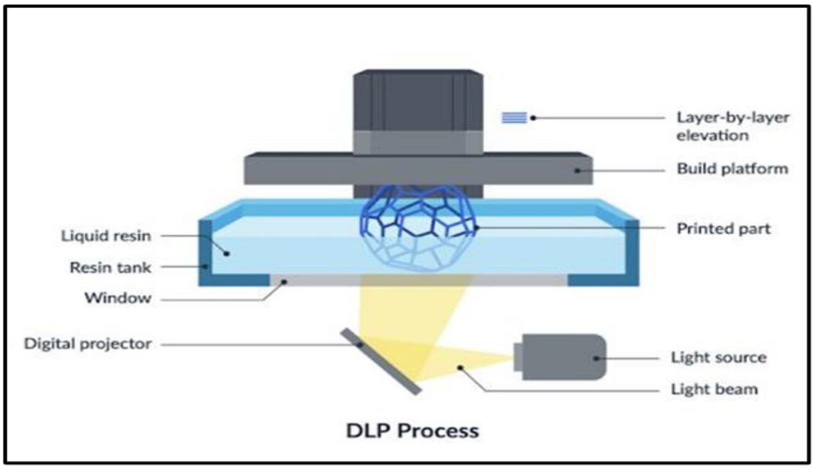

Figure 1: Parts of DLP printer (Hogan, 2023).

III. **Stereo lithography apparatus (SLA):**

The earliest 3D printing technology in the history of additive manufacturing, SLA is still in use today. In 1986, 3D Systems, Inc. co-founder Charles Hull filed a patent for this technique. A stereo lithograph apparatus (SLA) is a specially created 3D printing device used in the printing process to turn liquid plastic into solid 3D things. SLA printing technology is different from conventional desktop printers, which expel ink onto a surface. SLA 3-D printers use extra liquid plastic that eventually hardens and solidifies to create objects (Bhalerao, 2018).

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IV. **Selective laser sintering (SLS):**

SLS is a method that binds powdered material together to form solid structures by using a laser to sinter it. The material used is commonly nylon-polyamide, co-cr and the laser is automatically pointed at spots in space that are described by a 3D model. Since the pieces have high levels of stiffness and strength, this technique has many benefits, including superior chemical resistance. It can also build complicated items with channels and internal portions without trapping material within or changing the surface once the support has been removed. SLS's only drawback is the surface porosity of printed items. (Bhalerao, 2018).

Denture base liners

Relining is the procedure used for resurfacing of the intaglio part of a removable partial or complete denture with new base material, thus creating an accurate adaptation to the denture denture-bearing tissue (GPT, 2017).

The use of resilient denture liners may also be advantageous in providing successful construction of complete dentures by permitting the dentures to bear excessive forces of mastication where the denture bearing tissues are moderately intolerable in addition to their improvement of the intaglio denture surface (Korkmaz et al., 2013).

Viscoelastic properties of denture liners make them advantageous for using in dental practice. These resilient materials serve as a caution for shock absorption which will cause the pressure applied on denture-bearing tissues to be decreased and equally distributed. The use of resilient denture liners may also be advantageous in providing successful construction of complete dentures by permitting the dentures to bear excessive forces of mastication where the denture bearing tissues are moderately intolerable in addition to their improvement of the intaglio denture surface (Bolayir et al., 2007; Korkmaz et al., 2013).

1. Indications of denture lining:

Soft denture lining materials includes many applications (Hatamleh et al., 2010; Hahnel et al., 2012):

A. To re-adjust an ill-fitting and poorly adapted denture due to ridge resorption.
B. Immediate denture relining during healing period of wound after tooth elimination where the resorption of the residual ridge occurs.
C. Patient not able to tolerate the contact between hard denture material and the underlying soft skinny mucosa so, using soft liner will reduce pain due to its high resiliency.
D. Loss of tissue support in patient with CI-I or CI-II Kennedy classification of residual ridge, this will cause rotation of the free end extension of denture or occlusal-contact loss.
E. Make equalization of occlusal loads.
F. Enrichment of patient's grinding efficiency.
G. Better prosthesis retention via the engagement of modified abutments, Undercuts at the defected area and over denture-bar connection.
H. Mental or physical disabilities, making the patient unable to tolerate periodic visits for new denture fabrication.

2. Contraindications of denture lining:

Soft denture lining materials also had limitation in using (Knechtel and Loney, 2007):

A. Residual ridge with vast resorption.
B. Patient with an ill-fitting prosthesis for long time leading to unhealthy soft tissues.
C. Excessive bony undercuts.
D. Incorrect jaw relationship.
E. Old ill- fitting denture causing speech problems to the patient.
F. Fracture problems of denture base, where using of lining material will reduce thickness of denture base decreasing the base strength so the prosthesis may be fractured earlier.

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3. Classification of denture lining materials:

According to consistency of relining materials, they can be classified as follows (Takahashi et al., 2011; Van Noort, 2014):

I. **Tissue conditioning materials:**

These are resilient soft plastic materials that can be applied as temporary material to act as cushion to avoid force transmission to the hard and soft dental tissue, so it provides protection to the lower mucosa from being traumatized (McCabe and Walls,2008).

They present as powder and liquid system. The powder be made of pol ethyl methacrylate and the liquid involve an aromatic ester-ethyl alcohol mixture of 30% (Craigs et al., 1996).

One of the main drawbacks associated with denture lining materials is the failure of bonding between soft lining material and the denture base. This adhesion failure generates an environment which will be favorable for microbial progression, dental plaque accumulation, color alteration, calculus development, stiffness and dimensional changes. The tissue conditioner may be used either for short time period (few days to week) or long period of time (up to a year) (Yanikoglu and Denizuglu, 2006; Kimoto et al., 2013).

II.**Hard denture liners:**

Cold cure type. This type is directly applied and utilized to improve the retention and stability of partial-dentures, complete denture with poor fit and as temporary liner material for immediate dentures, so it is called chair-side relines systems (Murata et al., 2008).

This type of hard liner consists of the similar component, same degree of dimensional stability and surface properties of auto polymerized acrylic resins of the denture base material (Bunch et al., 1987). Most commonly, they are available as a powder and liquid system and can be divided into two categories, type I and type II in relation to their liquid type Where in type I, the liquid encompasses methyl methacrylate as a monomer while the other type, the liquid involves butyl methacrylate as a monomer (McCabe and Walls, 2008).

Heat cure type. This type is like the resins of the denture base. The initiation of polymerization relies on heat and the necessary way for their curing completed by water bath system (Schneider et al., 2002).

Another technique for relining by using light cure resin liner was introduced. It delivered in two forms: paste form and powder/liquid form. This technique having many advantages for instance biocompatibility, no any access element after achievement of the polymerization, good strength, color stability, free methyl methacrylate is not existing, suitable working time, accurate adaptation, less thermal irritation and simplicity of finishing (Murata et al., 2008).

III. **Soft lining material:**

A soft denture-lining may be defined as a resilient and elastic material comprising all or, a part of the intaglio surface of a removable denture base (Mutluay and Ruyter, 2005).

Soft lining materials are proposed to have elasticity, being energy absorbing, and serve as a cushioning layer (Bail M. et al., 2014).

The soft-liner application to the dentures can also improve the patient’s masticatory performance, biting force and the rhythm of chewing (Ergun and Nagas, 2007). In terms of serviceability resilient lining materials are either long-term or short-term products. Long-term soft denture liners preserve their elasticity for a period exceeding a month and is used for a maximum of a year, while short term soft lining materials are suggested for usage for a period up to one month (Kreve and Dos Reis, 2019).

Soft liners are viscoelastic, compliant materials used to portion reline or all denture’s fitting surface (Shanmuganathan et al., 2012). They are occasionally added to the fitting denture base’s surface to enhance the fit of the denture and to aid in the recovery of wounded soft tissues; they assist in avoiding concentrations of stress and affect the mucosa's ability to heal as well as providing comfort to the patient (Mutluay and Ruyter, 2007; Tabatabaei et al., 2020).

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They are able to form an absorbing layer on the part of denture in contact with the oral mucosa, and this allows less traumatic transmission of occlusal forces (Mohad and Fatalla, 2019; Brożek et al., 2011).

To serve their functions, they may also incorporate PMMA in combination with other monomers and plasticizers. Denture soft lining materials such as silicone elastomers and polyphosphazine fluoroelastomers are also available (Tabatabaei et al., 2020).

Silicone – based soft liners

Elastomeric silicone-based polymers are composed of poly vinyl siloxane materials (addition-type silicones), which have a chemical similarity to silicone impression materials.

There are two types: auto-polymerized and heat polymerization. silicones have several characteristics such as outstanding resistance to heat, low biocompatibility, high oxygen penetrability, reduced wettability, tremendously low surface tension, low glass transition temperature, resistance to radiation, superior rheological properties and excellent electrical isolation (Dogan et al.,2007).

Silicone lining materials are highly resistant to thermal variations, low degree of degradation, and high tear strength. Silicone soft lining materials display superiority in mechanical properties with a longer service life when they placed in comparison with acrylic based liners; nevertheless, they lack adhesion to the denture foundation, which is often made of PMMA-based polymers. The compositional difference among silicone lining materials and the denture base results in the lack of chemical interactions between them, and this the main cause for bonding failure which is often detected in denture base relining (Cavalcanti et al., 2014).

1. Auto polymerized silicone soft liner (chemically activated):

As soft lining materials, two types of cold curing silicone elastomers are used. The two varieties of silicone elastomers used as impression materials condensation and addition-curing silicone are comparable to them. Condensation-curing types are often supplied as a paste and catalyst liquid, and are laboratory prepared to the denture base fitting surface. A hydroxylterminated poly-dimethylsiloxane liquid polymer and an inert filler are used in the paste. The liquid comprises a cross-linking agent, such as tetraethyl silicate, and a catalyst, typically an organo-tin molecule like dibutyl tin dilaurate. These silicones produce significantly less cross linking than heat cure silicones, which compromises many of their long-term lining qualities and shortens their service life (McCabe and Walls, 2008).

2. Heat polymerized silicone soft liner:

These materials are purchased as a single paste. They are made of a polymer called polydimethylsiloxane that has terminal or pendant vinyl groups that enable for cross-linking. The liquid polymer is changed into a paste by addition inert-fillers like silica. Additionally, during heating, the paste's free radical initiator, like peroxide, degrades and starting the crosslinking-reaction. The vinyl groups are extended and cross-linked. Chain extension processes increase the viscosity of the liquid polymer, whereas crosslinking imparts flexibility to the substance (McCabe and Walls, 2008).

Problems associated with soft denture lining materials

The clinical efficacy of soft-lining materials was well documented, but their usage was frequently discouraged due to poor physical characteristics that are reported as follow:

A. The most critical problem is debonding of the lining material from the denture base, which can lead to bacterial growth and faster soft liner deterioration (Xiaoqing et al., 2015).
B. The increased porosity of resilient lining materials clinical use can lead to plaque accumulation and Candida albicans colonization (Rodrigues Garcia et al., 2003).

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C. Long-term usage of the lining materials would result in leaching of soluble components, such as plasticizers, which would impair the softness and bond strength of the lining materials (Kim et al., 2014)
D. The soft lining material swells due to water sorption leading to stress build up between the bonding surfaces, Brittleness in the material causes it to transfer external loads to the bonding area, failing the bond (Muralidhar et al., 2012).
E. Early fractures as a result of the denture thickness being reduced during the soft-liner application procedure is one of the primary causes of failure. Denture reinforcement could be used as a substitute to reduce and avoid prosthesis breakage (Lassila et al., 2010).
F. Surface imperfections and porosity, persistent flavor after use, propensity to absorb odors, susceptibility to color change, and difficulty to clean (Kreve and Dos Reis, 2019).
G. This material has to be replaced often (Shanmuganathan, N. Padamanabhan et al., 2012).

Methods of enhancement of soft liner to denture base materials

Bonding failure between denture base and lining lead to an environment which was favorable for bacterial colonization and also affects the soft-liner durability. The bonding between acrylic and liner depends on several factors including the surface geometry, etching, use of bonding agents, and the lining material thickness; several chemical and mechanical procedures are carried on to increase bonding strength and adhesive properties of lining materials (Hashem, 2015).

However, findings of numerous previous studies have suggested that treatments chemically are more efficient in improving adhesive strength (Cavalcanti et al., 2014). Surface preparation using acetone and other organic solvents, such as methyl methacrylate monomer, methylene chloride, maleic anhydride and ethyl acetate (EA) have been estimated as one of chemical surface treatment methods (Sarac et al.,2006). These chemical compound’s purpose to encourage a slight degree of degradation and dissolution in the surface of acrylic denture base, which allows mechanical interlocking and adhesive penetration, which enables the chemical bonding with the denture liner (Demir et al., 2011).

The aim of these mechanical surface modifications is increasing roughness of the surface and the micromechanical-interlocking of relining materials. These findings of numerous previous studies have suggested that treatments with chemical are more efficient in improving adhesive strength (Minami et al., 2004; Cavalcanti et al., 2014; Naji, 2020). Surface treatment with solvents, like acetone, methyl-methacrylate monomer, methylene chloride, maleic anhydride and ethyl acetate have been estimated as one of chemical surface treatment methods (Sarac et al.,2006).

These chemical compound’s purpose to encourage a slight degree of degradation and dissolution in the surface of acrylic denture base, which allows mechanical interlocking and adhesive penetration, which enables the chemical bonding with the denture liner (Demir et al., 2011; Cavalcanti et al.,2014).

Shimizu et al. (2006) concluded that ethyl acetate is a better replacement to dichloromethane for improving denture base repair, since dichloromethane is no longer recommended for the usage in dental practice because of evidences of its carcinogenic effect. it was suggested that the result of surface treatment with ethyl-acetate solvent for 120 seconds and the surface application of dichloromethane for 5seconds have the same effect. These findings can be explained in part by the exposed fresh denture base resin surface, an increase in the repair area, and the roughened structure of the cold cure acrylic repair resin, in addition to surface swelling, which allows PMMA diffusion and increases surface porosity. SEM pictures of the surfaces of denture undergone ethyl-acetate surface treatment confirmed the propensity for dissolution to progress deeply in ratio to surface preparation duration.

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Ethyl acetate

Ethyl acetate (CH3–COO–CH2–CH3) is the acetate ester formed between acetic acid and ethanol and has a role as a polar aprotic solvent, (Figure 2).

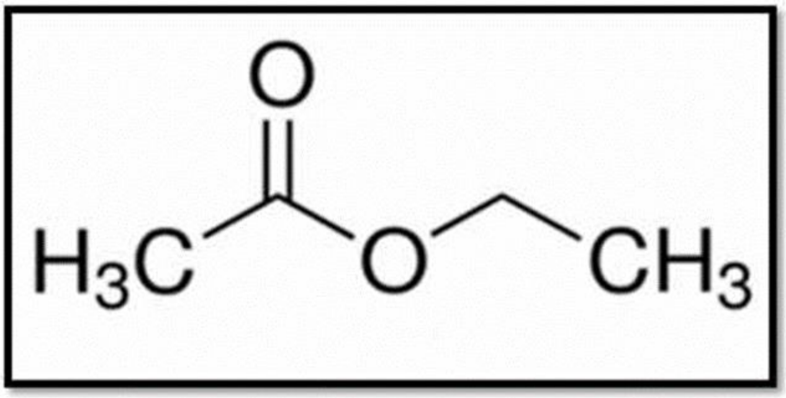

Figure 2: Chemical structure of ethyl acetate (Merck, 2023).

Ethyl acetate is a non-polymerizable organic solvent with the capacity of surface swelling and permitting of polymerizable material diffusion. The technique of remaining monomer extracting from resin was testified with the purpose of detect the remaining monomer concentration by the use of gas chromatography with a variety of organic solvents, such as ethyl acetate, chosen for their physicochemical qualities (Shimizu et al.,2006).

Previous observations by Shimizu et al., 2006 indicated that ethyl acetate also has the capacity of surface swelling and thus promoting denture base resin diffusion in addition to the creation of a degree of surface porosity which have an optimal effect on the bonding strength. This study concluded that the 120 seconds surface treatment with ethyl acetate solvent presented with the greatest bonding strength among 4 tested surface preparations and believed to have a close correspondence to the 5seconds surface preparation with dichloromethane.

Ethyl acetate 99.95% is also regarded as a safe surface treatment mediator which is not included in the International Agency for Research on Cancer's classification. It was found that ethyl acetate can swell the surface of base of denture and thus promoting the formation of interpenetrating polymer network and strengthening the bond among the soft-lining and base of the denture (Shimizu et al., 2008).

Conclusion

Ethyl acetate surface treatment had no chemical change to 3D printed acrylic resin and successfully dissolved the surface of 3D printed acrylic denture base material. Also, ethyl acetate surface treatment enhanced the bond strength.

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