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Adhesion of 3d printed acrylic resin with silicone soft liner after sandblast surface treatment (A Review of Literature)

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Abstract:

This literature review emphasizes the impact of aluminum oxide sandblast particles as a surface treatment agent on bond strength of heat-cured and 3D-printed polymethyl methacrylate denture bases and silicone soft liner. Denture soft liner materials play a crucial role in prosthodontics by enhancing comfort and tissue adaptability for denture users, as well as restoring irritated and deformed mucosa. The primary disadvantage of denture soft liner is the separation of the lining material from the denture base, known as debonding. Hence, it is important to improve the cohesion of these parts.

Keywords :sand blast , 3-dimentional, Polymethyl methacrylate, Softliners, Silicone.

Introduction:

Polymethyl methacrylate (PMMA) is widely used for making removable conventional dentures because it is easy to manufacture and repair, biocompatible, pleasing visual properties that improve patient acceptability. and has exceptional physical and mechanical characteristics, making them a good option for removable dentures (Mohammed and Farhan, 2024; Alqutaibi et al. 2023). Nevertheless, the traditional manufacturing procedure for fabricating full dentures for elderly edentulism individual, might be burdensome owing to the several appointments. Moreover, reconstructing dentures in the event of loss or breakage has difficulties. Recent developments in computer-aided design and manufacturing (CAD-CAM) have made it possible to create precise full dentures. This advanced method greatly reduces the number of visits needed for fabrication. In addition, the capacity to save digital data enables the convenient reproduction of denture (Park et al. 2022)

Digital denture bases are produced using two primary methods: subtractive and additive fabrication. Producing items by constructing them layer by layer is called additive manufacturing or 3-Dimentional(3D) printing technique (Schweiger et al. 2018;Anadioti et al. 2018).

The term "relining" describes the procedure of using new base material to resurface the inside of a removable dental prosthesis. This ensures that the denture fits accurately against the tissue that supports it (Feiruz and Mahmood, 2023; Ferro et al. 2017). Relining materials are used to adjust dentures to avoid excessive residual bone resorption, cure xerostomia, manage bony undercuts , thin and non-resilient mucosal tissue, and reduce persistent discomfort in patients (Surapaneni et al. 2013).

Surface pretreatments are usually required to improve bond strength with lining materials in polymeric materials. The relined denture may be maintained from breaking away from its base using various methods that establish a strong adhesive bond between the surfaces (Usumez et al. 2004;Awad et al. 2023). Studies have shown that surface treatments such as roughening by airborne particle abrasion, may enhance adhesiveness on heat cure acrylic. Sandblasting is a frequently used technique for altering surface roughness in order to improve the strength of bonding (Hamedirad et al. 2021; Yurttutan et al. 2018).

The inadequate adhesion of lining materials to the PMMA material is a major problem. This may lead to surface germ proliferation and the deposition of calculus and plaque (Farzin et al. 2013).

Denture base material:

The denture base is the part of the removable dental prosthesis that is located on the foundation area and holds the teeth (Ferro et al. 2017). Prosthesis creation to replace missing teeth using different materials is not a new concept, since it has been mentioned throughout history. Dentures were made in the 1700s from ivory, wood, whale, or hippopotamus bone and carved to suit edentulous areas, but they were costly since they were difficult to make and required talent (Hargreaves 1980; Hargreaves 1981). Many different materials have been attempted as denture materials, and in 1774, Alexis Duchateau introduced porcelain materials. John Greenwood attempted to utilize gold as denture material in 1794 AD (Tandon et al. 2010).

Requirements of denture base materials:

The desired properties of denture base materials have been determined. Nevertheless, none of the currently accessible items meet all of the specified criteria. Hence, any material that has a balanced combination of all the necessary qualities would be the preferred option. These requirements were identified by (Manappallil 2015; McCabe et al. 2013)

1- Excellent strength and durability, with high resistance to wear and abrasion.

2- Satisfactory thermal characteristics.

The material remains dimensionally stable and does not experience any expansion, contraction, or warpage throughout processing.

4- Nice flavor and scent.

Biocompatibility refers to the ability of a material or substance to be compatible with living tissues or organisms without causing harm or adverse reactions.

6- Stability of color.

7- Natural appearance.

8- Excellent adherence to plastic, metal, and porcelain.

9- Simple manufacturing and restoration.

10- Radiopacity refers to the ability of an object or substance to block or absorb X-rays, making it visible on a radiograph or X-ray image.
11- This substance does not support the development of germs and fungus and may be effectively cleaned.
12- Affordable price and long-lasting durability.

Types of denture base material:

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 (Anusavice et al. 2012).

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. Polymerization proceeds similarly to how heat activated systems do (Anusavice et al. 2012).

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 2005).

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 (Abd Alrazaq and Khalaf; 2023, Anusavice et al. 2012).

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. 2004).

6- Subtractive or milled CAD/CAM acrylic:

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 et al., 2011). The milled denture appears to have better physical characteristics, the resin is more hydrophilic, for instance (wettable)(Sipahi et al., 2001) has fewer residual monomers (Ayman,

2017; Steinmassl et al., 2017) In addition, the milled denture is denser than heat-activated traditional denture base (Ali et al., 2008; Ayman, 2017)

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 (Kattadiyil et al., 2015; Murakami et al., 2013). It is most likely a result of the processing technique using high temperature and pressure, which led to a low concentration of monomer residue.

7- Additive or 3D printing acrylic resin:

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

A composition consists of a light-curable viscous mixture that includes:

- 0-50% by weight of a PMMA solution
- 25-65% of the total weight consisting of one or more difunctional bisphenol-A dimethacrylate compounds
- 5-40% by weight of one or more types of aliphatic urethane (meth)acrylate oligomer
- 5-20% of the total weight consisting of one or more varieties of multifunctional aliphatic (meth)acrylate
- 0.1-5% photoinitiator
- 0.05-2% light stabilizer
- 0.1-3% color pigment

These percentages are based on the total weight of the composition

CAD/CAM technology:

CAD/CAM, a modern method for making dentures, is becoming more common in dentistry (Alshaikh et al., 2022; Tasaka et al., 2019). There are several advantages to CAD/CAM prostheses for both the dentist and the patient (Al-Dwairi et al., 2019; Batisse & Nicolas, 2021). In some instances, these dentures may be fabricated during just two appointments, resulting in a notable decrease in both clinical and patient time (Murray & Darvell, 1993). Manufacturing businesses use digital scanning and storage methods to preserve medical data. Therefore, if a patient loses or damages their denture, there is no need for modifications or new medical data. This allows for the prompt creation of an identical replacement prosthesis (Goodacre et al., 2016; Rueggeberg, 2002) Dentures may be created by either subtractive procedures, such as milling, or additive ones, such as 3D-printing (Batisse & Nicolas, 2021; Goodacre et al., 2016; Ring, 1985)

Subtractive manufacturing :

Subtractive manufacturing (SM)is the mechanical elimination of unwanted portions from a pre-polymerized resin block to create a complete prosthesis. The milling machine is controlled by a computer, which accurately executes the designated design (Beuer et al., 2008; Ring, 1985). This technique is often used for fabricating simple restorations and crowns. There are two methods for manufacturing full dentures utilizing SM. The first method involves acquiring a conventional impression of the edentulous area to create an exact copy. Next, a wax model with the arrangement of teeth is produced, and subsequently transformed into a digital format using a digital scanner. The

digital file is then sent to computer-aided manufacturing (CAM) equipment. ultimately, The CAM machine carves the whole denture from a plastic material block. The second approach involves obtaining a digital impression of the edentulous area, which is promptly sent to the CAD software. The CAD application generates a comprehensive denture according to particular requirements given by the physician or technician. This method eliminates the conventional procedure of making impressions and physically sculpting the wax and teeth. After the denture design is completed, it is delivered to the computer-aided manufacturing (CAM) equipment, which is the last step in the denture production process (Bilgin et al., 2016; Rekow et al., 1991)

Additive manufacturing (rapid prototyping):

The application of 3D printers in additive manufacturing has received interest for many reasons, including production, health care, research, and education. In prosthetic dentistry, additive manufacturing's ability to manipulate material using CAD data affects prosthesis quality, mechanical properties, cost, and production time (Al-Sammraaie and Fatalla,2023). Additive manufacturing (AM), in contrast to (SM), is often used for fabricating the prostheses. AM is the process of using CAD software to create a 3D model, which is then used to combine materials together to make the required form. The quick prototype process begins after the CAD design is divided into layers. The ultimate objects is built incrementally, with each layer being added sequentially(Alghazzawi, 2016) The material often used for additive manufacturing of dental products is liquid polymer resin. Curing is frequently needed to produce the necessary strength in the final result (Alghazzawi, 2016; Stansbury & Idacavage, 2016). Additive manufacturing (AM) offers a notable benefit by reducing material waste compared to subtractive manufacturing (SM) by exact layering according to the form specified by computer-aided design (CAD) software(Dawood et al., 2015)Additionally, AM has a superior capability in creating undercuts compared to SM (Skordou et al., 2021). Additive Manufacturing (AM) encompasses a range of specialized methods designed to accommodate diverse materials and applications(Chia & Wu, 2015)

denture base Soft liner:

One of the main characteristics of bones is their plasticity which allows them to undergo changes in shape and structure in response to many known and unknown factors. This may limit the adaptation of the denture base to the underlying tissue (Bowman & Javid, 1977). Two choices exist for enhancing the denture base's fitting surface. Using new heat-cured acrylic resin for the old tissue surface on the complete denture foundation is the first choice. or line the denture base with a soft material, and to make denture bases fit better, several lining materials are used., and their primary function is to absorb shock and cushion the tissue to reduce force on damaged areas and aid in tissue recovery (Kubo et al., 2014; McCabe & Walls, 2013).

Resilient liners are divided into short- and long-term liners. Short-term liners are made for a 30-day duration, while long-term denture liners preserve their resiliency for more than 30 days and may be worn for up to 1 year. (Abdul-Baqi et all.,2022).

Relining refers to the techniques used to resurface the inner part of a removable dental prosthesis with fresh base material, resulting in a precise fit to the denture foundation region"(Ferro et al., 2017;Alkinani.,2014**)**Consequently, several lining materials have been created to ensure the even

distribution of functional and non-functional occlusal force, as well as to provide cushion support and improve denture retention (Aziz., 2017).

Advantages and indications of denture relining:

The outcome of the denture relining procedure depends not only on the characteristics of the soft liner materials but also on a knowledge of the specific issues where these materials may be effectively used.

1. Clinical instances characterized by the presence of persistent tissue ulceration, thinning of tissues, and resorption of remnant alveolar ridges.
2. The aim is to improve the fit of the denture surface and prevent damage to the oral mucosa by creating a cushioning layer between the mucosa and the denture foundation.
3. They assist in securing dental and facial prosthetic devices by facilitating the use of modified abutments or overdenture-bar attachments. They are also used in maxillofacial obturators to fill in gaps in the defect area.
4. Used as an immediate complete denture after 3 to 6 months of insertion.
5. The patient has financial constraints and is unable to pay for a new denture (Ferreira et al., 2009; Hatamleh et al., 2010).

Contraindications of denture relining:

If any of the following conditions, in addition to the poor fitting of the denture base, are present, it is recommended to either rebase or fabricate a new denture (Knechtel & Loney, 2007).

1) Severe ridge resorption.
2) Soft tissue ulcers due to the poorly fitted denture base.
3) Patient presenting with temporomandibular joint (TMJ) disorders, specifically exhibiting alterations in centric relation.
4) Patient presenting with cosmetic concerns.
5) Malocclusion of dentures.
6) Inadequately fitted denture base resulting in speech difficulties.
7) The bony undercuts are quite acute and deep.
8) Denture base fracture.

Issues associated with soft denture liner materials:

The application of denture soft liner presents several issues, including the detachment of the soft liner from the denture base, reduced flexibility, changes in color, weak tear resistance, and the formation of pores that can accumulate plaque and be colonized by Candida albicans (Kreve & Dos Reis, 2019; Xiaoqing et al., 2015). A significant drawback of lining materials is their inadequate adhesion to the PMMA material, which may result in the growth of germs on the surface and the deposition of plaque and calculus. Several variables may affect the binding strength between soft lining materials and the denture base. These factors include water sorption, the use of surface primers, and the deterioration of the denture base. During clinical use, the accumulation of pores may lead to the formation of plaque and the colonization of Candida albicans(Farzin et al., 2013).

Factors for enhancing the bonding between soft liner and denture base materials:

Bond strength is the force required to break the bond together with failure happening in or close the adhesive/adherence interface (Ferro et al., 2017). An important issue related to the use of soft

lining materials is the breakdown of the connection PMMA denture base and denture liner. A significant drawback of soft lining materials is their weak adherence characteristic, as seen in clinical studies (Rao et al., 2012). The binding strength of soft liners is influenced by many factors, including the chemical composition of the soft liners. If the composition differs from that of the denture surface, it might create a gap between the two surfaces. This gap can then contribute to the buildup of microorganisms. For instance, when utilizing a silicon-based soft liner that lacks chemical bonding with the denture base, it is necessary to use bonding agents in order to optimize the strength of the link between them (Sarac et al., 2006). Additionally, immersing dentures in water may have a negative impact on the bond strength. This is because the resilient liner may absorb water and exert pressure on the denture surface, leading to stress concentration and bond failure. As a result, there can be a change in the viscoelastic properties of the denture (Kulak-Ozkan et al., 2003; Mese & Guzel, 2008).

Various techniques were used to improve the bond strength, including modifying the surface of the denture base that comes into contact with the soft liner. This was achieved through methods such as using lasers, applying chemical etchants, enhancing the bond Strength with acrylic burs and using alumina abrasion (Hatamleh et al., 2010). Furthermore the cross-linked polymer in 3D-printed resin demonstrates high stability for both monomers and acetone, as described (Park & Lee, 2022).

Sand blasting:

Blasting process, a well-known technique in industrial surface preparation, uses a variety of abrasive blast media. The blasting media vary in form, ranging from round to angular, and come in varying sizes, ranging from tens of microns to hundreds of millimeters. Examples of blasting media include glass, steel, coal slag, alumina, garnet, walnut shells, polymers, and more. To ensure adequate bonding with the substrate, it is necessary to obtain good surface preparation by using hard and angular abrasive particles such as alumina. This will provide a sufficient surface profile with the appropriate roughness (Antoš et al., 2023).

Investigators attempted to enhance the bonding strength by roughening the surface of the denture base material using airborne particles before applying the liners. There is controversy over the effectiveness of sandblasting in enhancing the strength of a connection. Several studies have shown enhanced bond strength. Whereas others have found that mechanical surface treatment of DBR reduces adhesion bond strength (Hamedirad et al., 2021).

Conclusion:

surface treatment by aluminum oxide sand blast particles improve surface roughness that lead to increase denture soft liner adhesion to denture base material.

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