



Acrylic Resin Denture Base Material Enhancement by Fiber, Filler, and Nano Filler Addition: A Systematic Review

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Abstract

Background: In the current study, two wt. concentrations of strontium titanate (SrTiO₃) Nano powder (1% and 1.5% wt.) were added. An evaluation was conducted on some properties of heat-cured Acrylic Resin. **Aim:** to investigate how introducing SrTiO₃ (NPs) Nanoparticles in amounts of 1% weight and 1.5% weight impacted some of the mechanical and physical properties of heat-cured denture base material and describe the results of adding (Strontium Titanate Nanoparticles) to Heat Cure Acrylic Denture Base Material. **Materials and methods:** An Electronic Systematic Review was conducted in different databases: (Science Direct, PubMed, Web of Science, and Google Scholar searches) were consulted on this topic, as well as on a hand search of the scientific literature. Published writings from 2015 to 2022 were obtained, examined, and relevant articles were chosen for this review. The online databases were used to perform a literature search for publications published until 2022, without any date or language restrictions. The overview highlights the most significant developments in this field, demonstrating how resin technology developed in many ways. **Results:** Acrylic Resins' Mechanical and Biological Qualities have been enhanced through the surface modification of poly (methyl methacrylate), the addition of Natural or Mineral Fibers, Fillers, including Nano fillers, and/or Fillers. The post-polymerizations activity decreased the quantity of leftover monomer. New Varieties of Acrylic resins were created for the processing of computer-aided design/computer-aided manufacturing systems and three-dimensional printing. The findings suggest that current knowledge is to use acrylic resin in different cases of dentistry with SrTiO₃ NPs and acrylic resin. that consider the most esthetic material and more comfortable, good Strength and Resistance to Wear. **Conclusions:** that addition of SrTiO₃ Nanoparticles into denture base acrylic material improves transverse Strength, Surface Hardness Values, and Glass Transition Temperature, with a Negligible decrease in Surface Roughness.

Introduction:

German chemist Rohn created acrylic resin for the first time in 1900, and after Kultzer patented it in 1940, it has been widely utilized in dentistry and medicine ever since. The polymer is created by (MMA) in an Aqueous Environment. Using this method, small (PMMA) Balls with a diameter of 40 to 100 m are created ⁽¹⁾. Technology advancements in polymer manufacture require rapid MMA synthesis. Crawford developed this quick synthesis method in his early 30s. Chemicals that are easily accessible are used in this method, including acetone, sulfuric acid, hydrocyanic acid, and methanol. At the moment, PMMA is widely made using this technique. A polymer that is strong to lipids and isopropyl alcohol (IPA) is produced using this technique. PMMA's strong white light transmittance of 92%, which gives the denture a natural appearance, is a very significant quality. sterilized with gamma radiation, ethylene oxide, or an e-beam ⁽¹⁾. Major developments in dentistry have been made recently. Dental technician human labor has gradually been replaced by technology such as three-dimensional (3D) printing and computer-aided design/computer-aided manufacture (CAD/CAM Interim crowns, bridges, and surgical guides are routinely milled using CAM discs composed of PMMA resin. Additionally, many manufacturers offer pre-made polymerized pink discs that are cut into the shape of a denture foundation and attached with acrylic teeth. The mechanical properties of polymerized PMMA in disc form are superior to those of the material polymerized in the dental laboratory. When the polymerization process is run under high pressure, for a longer period of time, and with a bigger ratio of powder to liquid, a higher cross-linked material with a very low residual monomer concentration is eventually formed ⁽²⁾. Better mechanical properties are offered by fixed dental prostheses manufactured of CAM discs that have undergone industrial polymerization. As opposed to glass ceramic and regular PMMA resin restorations, these prostheses

were shown to have an initial fracture load of three-unit restorations ⁽³⁾. They also seem to have acceptable optical qualities and discoloration resistance ⁽⁴⁾. A lesser hardness than dental ceramics, which results in less wear on the opposing dentition's natural teeth, is another noteworthy advantage ⁽⁵⁾. Several methods have been employed to enhance mechanical properties, including chemically rectifying the polymeric structure by the inclusion of particular elements ⁽⁶⁾. Nanotechnology used in dentistry was in term of 'Nano dentistry'. It comprises of diagnostic tools and therapeutic that used nanomaterials to service in the maintenance of oral hygiene. Holistically, nanoparticles in dentistry studies were developing but slowly ⁽⁷⁾. Adding fibers and particles to acrylic resin is another way to make it better. Polymers frequently have micrometer- and nanometer-sized fillers added to them to boost stiffness and strength, enhance solvent resistance, or cut costs ⁽⁸⁾. Titanium with strontium oxide together up the chemical compound strontium titanate (SrTiO₃). It's a well-liked substance for thin oxide sheets and superconductors. In order to create scaffolds for bone regeneration, strontium titanate Nano powder can be employed ⁽⁹⁾. In order to improve some of the properties of maxillofacial silicone at room temperature, nano SrTiO₃ was employed as a filler in the material ⁽¹⁰⁾.

Procedures and Materials

The on-line databases of Google Scholar, PubMed, academic search, and Z-library were tried to search for the advantage and properties of acrylic resin and uses of these materials in dentistry. Criteria for inclusion have been research articles between 2015 and 2022 that learned. The purpose of this review is to provide a practical and scientific overview of acrylic resin and their uses in dentistry. We summarized the classification and characteristics of actual used in dentistry in this review. The current work makes an effort to present research challenges and future directions in addition to studying the literature that already exists on

different material used. The results of the current study will be helpful for practice in all areas of dentistry that are interested in further study.

Properties and Technologies of PMMA Dental Resin

There are two primary categories of acrylic Materials on the market right now: those that polymerize at Room Temperature (RT) and those that must be processed at high temperatures (HT). Self-Curing Resins are the first class of materials. More benzoyl peroxide is included in the powder as a reaction catalyst for these substances. Tertiary amines or ammonium salts and ethylene glycol dimethacrylate (EGDMA) are also present in the liquid in trace concentrations. These are utilized as low-temperature polymerization catalysts in extremely low concentrations (below 2%). Di methacrylate is found in high-temperature materials at concentrations of 5%, which increase the hardness of Acrylic Materials while decreasing Sorption and Solubility. curing polymers are often utilized in pouring processes to manufacture individual impression trays, create removable orthodontic appliances, fix fractured dentures, and create removable interim dentures ⁽¹¹⁾. The mechanical properties of thermally polymerized acrylic polymers are superior to those of traditional self-curing resins. These high-temperature resins have a fracture resistance of 80 to 95 MPa when compared to Self-Curing Materials. Similar to this, the development of goods that do not readily discolour in the oral environment is made possible by the capacity to cure at a higher temperature without using a lot of tertiary amines or benzoyl peroxide, as well as colour stability, sorption, and solubility ⁽¹²⁾. The manual work that dental technicians once did have been gradually supplanted by computer-aided design/computer-aided manufacturing (CAD/CAM) technology or three-dimensional (3D) printing. CAM discs made of PMMA resin are frequently used to mill interim crowns, bridges, and surgical guides. Additionally, several

manufacturers sell pre-made polymerized pink discs that are cut into the shape of a denture foundation and attached with acrylic teeth after being designed on a computer. The mechanical qualities of polymerized PMMA in disc form are better than those of the material polymerized in the dental laboratory. When the polymerization process is done at high pressure, for a longer period of time, and with a larger ratio of powder to liquid, a higher cross-linked material with a very low residual monomer concentration eventually forms. When the polymerization process is done at high pressure, for a longer period of time, and with a larger ratio of powder to liquid, a higher cross-linked material with a very low residual monomer concentration eventually forms ⁽¹³⁾. Better mechanical properties are offered by fixed dental prostheses manufactured of CAM discs that have undergone industrial polymerization. According to reports, these prostheses have an initial fracture load that is three units more than that of glass ceramic and regular PMMA resin restorations ⁽⁴⁾. Additionally, their optical properties and resistance to discoloration appear to be acceptable ⁽¹⁴⁾. Lower hardness is a significant advantage as well ⁽⁵⁾. A liquid material is initially put into a container with a transparent bottom to make a 3D object. This container's liquid contents are only partially illuminated by a laser or light beam traveling through an image with bright and dark areas. Due to all of these characteristics, fixed dental prostheses may be more suitable for usage as permanent or even long-term interim fixed restorations. MMA is not the only material utilized in 3D printing; higher derivatives of MMA that have two or more polymerizable groups are also used ⁽¹⁵⁾. To create a 3D object, a liquid substance is initially placed into a container with a clear bottom. A laser or light beam passes through an image with bright and dark regions, partially illuminating the liquid inside this container. because even after being removed from the printer and it is still soft. The thin coating of polymerized material is removed from the finished

product by washing it in an isopropanol solution after polymerization ⁽¹⁵⁾.

1. Mechanical Reinforcement

Dentures made of acrylic resin are brittle and prone to breaking when being chewed on, especially if the alveolar bone is thinning. Because of their reduced hardness, lower fracture resistance, and lower colour stability, acrylic materials are different from other prosthodontic materials (ceramics, metal) ⁽¹⁶⁾. As a result, numerous attempts have been undertaken to enhance their characteristics ⁽¹⁷⁾. The most widely used skeletal prosthesis includes a chrome-cobalt alloy framework for transferring chewing forces and solely employs acrylic to attach the teeth to the denture's metal framework. Unfortunately, not all clinical settings allow for the use of these prostheses. Metal mesh is frequently integrated into the acrylic denture foundation of removable acrylic dentures to reinforce them. However, this approach has the drawback of slowly forming a tiny gap between the acrylic and metal components of the denture during the denture service. The procedure can go more quickly if there is no chemical reaction between the metal and the acrylic layer ⁽¹⁸⁾.

2. Denture Base Reinforcement Material

Although alternatives like polycarbonates and polyamides have been developed, the most common denture base material on the market right now is PMMA ⁽¹⁹⁾. Every year, the number of thermoplastic removable partial dentures on the market grows, reflecting their growing popularity in dental practice. However, they are still viewed with some reservations in the academic community, particularly because the number of productions analyzing the physical and mechanical properties of these materials is still limited in the literature ⁽²⁰⁾. Due to this, numerous efforts have been made to enhance these properties, either by changing the chemical makeup of the resin or by adding reinforcement materials ⁽²¹⁾. The efficiency

of the reinforcement was shown to be significantly influenced by the concentration, size, adhesion, shape, and distribution of the filler particles within the polymer matrix as well as the strong adhesion at the interface ⁽²¹⁾. The idea behind strengthening by fibre reinforcement is that shear stresses at the interface in a polymer matrix may successfully transmit applied loads to fibre ⁽²²⁾.

Reinforcement Material

The reinforcement material can be classified into Fibers, Addition of metal oxides, Strontium titanate, Glass fibers, Zirconia Nano fillers, Titanium dioxide (TiO₂), and Polyethylene fibers.

1. Fibres

It serves as reinforcement and the primary load-bearing element. The fibers are contained and fixed by a continuous phase that the matrix creates ⁽⁵⁾. In order to strengthen the brittle material, the fibers utilized must be stiff; otherwise, they won't have much of an effect on the characteristics. The most important factor in determining the composite's strength is adequate fiber adhesion to the polymer, which enables stresses to be transferred from the matrix to the fibres. Adhesion can be enhanced by using a silane coupling agent ⁽²³⁾. An effective impregnation enables the resin matrix to make touch with the surface of each fiber, enhancing bonding. When the fiber concentration is gradually increased, even though larger, the characteristics of PMMA are significantly affected on concentrations ⁽²⁴⁾.

2. Addition of Metal Oxides

Acrylic resin has improved mechanical and physical characteristics by Addition of Metal Oxides ⁽²⁵⁾. Due to the unpleasant discoloration that appeared even with a very little amount of metal, metal-filled PMMA should only be utilized in regions where it is not visible. The resilience of this reinforced PMMA in the face of

chewing pressures makes it appropriate for usage in the posterior occlusal zones. The use of metal-filled resin is restricted to the palatal region of upper dentures and/or the lingual flanges of lower dentures because, despite this apparent discoloration, the metal reinforcement is still anticipated to reduce the incidence of breaking in acrylic dentures⁽²⁶⁾. The use of fillers greater than 5% by volume is restricted due to the fact that the tensile strength steadily reduced as the filler ratio increased⁽²⁷⁾.

3. Strontium Titanate

Strontium Titanate is denser than diamond, and it shares diamond's cubic crystal structure and refractive index (2.410 for SrTiO₃ and 2.417 for diamond). Strontium titanate is a preferred material for superconductors and thin films made of oxides. The electrical conductivity of SrTiO₃ can be improved by doping it with niobium. SrTiO₃ treated with niobium is a popular conductive single crystal material used in the production of perovskite oxides. Due to its excellent electronic and ionic conduction, strontium titanate is employed as a mixed conductor (oxidation catalysts, sensors, and electrodes in batteries and fuel cells) since it can transduce signals quickly⁽²⁸⁾. Strontium titanate nano powder is a type of material that can be used in a variety of electronic applications. A sort of material that can be used in many different electronic devices is strontium titanate nano powder. Bone regeneration scaffolds can be created using strontium titanate nano powder⁽²⁹⁾. Additionally, Strontium titanate nano powder was recently employed in a study to improve various silicone's qualities in maxillofacial silicone⁽¹⁰⁾. The mechanical properties of heat-cured acrylic will be impacted by the usage of strontium titanate nanoparticles. The alternate theory, however, claimed that adding strontium titanate to heat-cured acrylic would improve the material's mechanical qualities. Strontium titanate, often known as SrTiO₃, is a titanium and strontium oxide⁽³⁰⁾. In the late 1940s and early 1950s, strontium titanate was introduced as a synthetic material, along with other titanates like calcium and barium titanate.

The creation of strontium titanate was initially revealed by Leon Marker and Langtry E. Lynd in 1953. Over time, a number of advancements were made thanks to the inclusion of coloring compounds. The direct band gap of strontium titanate is 3.75 electron volts (eV), and the indirect band gap is 3.25 eV. High-band-gap materials offer better voltage capacity and can function at higher temperatures⁽³¹⁾.

4. Glass Fibers

Glass fibers have grown in significance as a PMMA reinforcement agent due to their alluring properties and strong adhesion to polymers via silane coupling agent. Due to reimpregnation, the glass fiber is manufactured to be simple to use, does not fray, and can be positioned in the correct location on the prosthesis. It has been demonstrated that glass fiber improves transverse strength, particularly fatigue resistance, mechanical qualities, IS, and FS, but not significantly bending strength or surface hardness⁽³²⁾. Because of their excellent adhesion to the denture base polymer, which transmits the stress applied to the matrix to the fibers, glass fiber's low percentage of elongation at break can be explained⁽⁵⁾. Another benefit is that because the fibers are holding the prosthesis' shattered parts together, they are more likely to stay close to one another in the case of a catastrophic failure⁽¹³⁾. Zirconia is a biocompatible substance with enhanced fracture toughness and strong fracture resistance.

5. Zirconia Nano Fillers

Zirconia Nano fillers have been found to improve PMMA's mechanical properties when added to acrylic resin⁽³³⁾. Studies show that adding ZrO₂ fillers considerably raised the fracture toughness and hardness. ZrO₂ was chosen due to its improved biocompatibility as well as its white color, which is less likely to detract from aesthetics were further factors in its selection⁽³⁴⁾. The nano-filler particles lead to no aggregation, better dispersion and greater compatibility with organic polymer⁽³⁵⁾. The improvement in mechanical

properties between the Nano filler and resin matrix may be caused by the formation of cross-links or supramolecular bonding that covers or protects the Nano fillers and, in turn, restricts fracture propagation. Complete wetting of the resin matrix is also another factor that contributes to this improvement in mechanical properties ⁽³⁶⁾.

6. Titanium Dioxide (TiO₂)

Is a white, naturally occurring mineral. “and” has excellent biocompatibility. Experiments revealed that TiO₂ fillers dramatically increased IS and fracture toughness while significantly reducing water sorption and solubility. In clinical settings, it is possible to prevent denture fractures and unfavourable physical changes brought on by oral fluids by adding certain amounts of metal oxide to heat-cured acrylic resins. is a mineral that is white and occurs naturally. This has excellent biocompatibility. Experiments revealed that TiO₂ fillers dramatically increased IS and fracture toughness while significantly reducing water sorption and solubility. In clinical settings, it is possible to prevent denture fractures and unfavourable physical changes brought on by oral fluids by adding certain amounts of metal oxide to heat-cured acrylic resins ⁽³⁷⁾.

7. Polyethylene Fibers

Polyethylene fibers are essentially imperceptible in denture base acrylic resins and are reported to improve the physical qualities of acrylic resin ⁽³⁸⁾. They have been discovered to raise the IS and elasticity modulus. Recently, highly drawn linear polyethylene fibers were created, and they had low water absorption, great stiffness and strength, and established biocompatibility ⁽³⁹⁾.

Surface Conditioning for PMMA

The interior of the dental prosthesis features a rough surface that promotes the growth and attachment of bacterial and fungal biofilms. Due to the hydrophobicity

and electrostatic forces of the denture material, this part is challenging to remove. Surface treatment may further improve PMMA's antibacterial and antifungal properties. It has been shown that using atmospheric pressure cold plasma to treat the polymerized material lowers the water contact angle and increases the wettability of the denture surface. Additionally, it significantly reduced *C. albicans* adhesion with no negative effects on the mechanical or surface roughness of the PMMA, which is encouraging for the prevention of Candida-related denture stomatitis ⁽⁴⁰⁾. As a result of photo polymerized coatings using hydrophilic (3-hydroxypropyl methacrylate) or zwitterion (sulfamethazine methacrylate) monomers, the hydrophobicity of PMMA is increased, significantly lowering *C. albicans*' ability to adhere to the surface ⁽²²⁾. An alternative would be to apply a nanocomposite film made of silane and SiO₂ to the surface of PMMA resin. Contrary to the techniques mentioned above, this coating significantly lowers *C. albicans* colonization while simultaneously reducing the wettability of the PMMA surface. The PMMA resin's flexural resilience and hardness are increased while its surface roughness, sorption, and solubility are decreased by the addition of this coating ⁽⁴¹⁾.

Strengthening of the Bond Between Metal Alloys and Acrylic Resin Teeth

The acrylic resin teeth must be firmly attached to the denture foundation. With acrylic teeth, which are polymerized at a high temperature under high pressure, it can be difficult to make a proper connection with the denture foundation when utilizing self-curing materials. When the acrylic denture base and acrylic teeth are not sufficiently connected, a microcap occurs. The discoloration is a result of dental plaque, food and drink residues, and discoloured teeth. Additionally, this encourages the colonization of microbes. Under extreme circumstances, the teeth and denture foundation may separate ⁽⁴²⁾.

The wax on the surface of the fake teeth needs to be carefully cleaned in order to ensure adequate adhesion between the denture, base and the tooth structure. You could use benzene, chloroform, or alcohol as wax solvents for this ⁽⁴³⁾. The contact surfaces of these two materials can be widened by either sharply contouring with aluminium oxide or by grinding the contact surface of the acrylic teeth in order to adequately connect them to the denture base. The acrylic tooth surface can also be slightly dissolved in MMA, acetone, or commercially available solutions ⁽²⁾. to establish a chemical interaction. Additionally, a higher temperature might make acrylic teeth's surface deterioration worse. Akin talked about a technique that involves irradiating acrylic resin with an Er: YAG laser to strengthen the bond between it and the denture teeth. Another efficient way to strengthen the link is by creating retentive holes. Numerous techniques can be used to strengthen the bond between the acrylic base and the feldspar ceramic teeth. Similar to acrylic teeth, they can be created either chemically or by extending the surface (sandblasting). Hydrofluoric acid has the ability to dissolve ceramic silica, considerably expanding the surface area. The next stage should be to use silanes, which are organic chemicals based on silicon. One of the compounds is SiOC_2H_5 . whereas the other easily hydrolyzers to form a bond with the ceramic surface, the first forms a double bond that can connect it to the acrylic chains. whereas the other easily hydrolyzers to form a bond with the ceramic surface, the first forms a double bond that can connect it to the acrylic chains. Due to the bonds that form between the ceramic and the PMMA resin, the final structure contains both a chemical one and physical link (surface expansion) ⁽⁴⁴⁾. Additionally, the surface expansion caused by sandblasting can be used to properly join the acrylic surface to the metal alloys or composite. Silanes and materials with phosphate residues and acrylic linkages, such as 10-methacryloyloxydecyl dihydrogen phosphate and 1-decarboxylic acid, 11-methacryloyloxyundecan-1, can be

beneficial for non-precious alloys ⁽⁴⁵⁾. The formation of a strong bond is more difficult with noble alloys since they don't have an oxide layer on their surface to which the aforementioned compounds could be connected. Consequently, chemicals with sulphur rings are needed. Currently, to achieve a strong bond between the acrylic and the composite material, commercial products that combine high-functional methacrylate and substances made from self-etching bonds are used ⁽⁴⁶⁾.

Addition of Natural Products in the literature

Information about PMMA modification by natural chemicals is available. For instance, Azeez et al. Enhanced polymer with natural pigments (vanilla, raspberry, curcumin, and amaranth) to make it more biocompatible ⁽⁴⁷⁾. materials with antibacterial and antifungal properties that can aid in the treatment and prevention of denture stomatitis were created by combining acrylic resins with chitosan salts. In a study, Zou et al. investigated the effects of bamboo cellulose nanofibers at different concentrations on the flexural strength, contact angle, and cytotoxic properties of restorations. Information gathered in a clinical context showed that the restorative adhesion and contact angle had significantly improved ^(46, 48). Either Neem or Aloe Vera increased thermal conductivity and shear bond strength of soft liner ⁽⁴⁹⁾. The Surface modification using silane coupling agent adhesive enhanced acrylic tooth denture bonding strength ⁽⁵⁰⁾.

Discussion

PMMA is the preferred material for denture bases. Due to its beneficial working characteristics, stability in the oral environment, accuracy in fit, low cost of equipment, ease of use, and superior esthetic, it was created by Dr. Walter Wright and is still in use today. Adding reinforcements to the denture base polymer was one approach to get over this problem. The concept of integrating

nanoparticles into a material matrix to build innovative composite reinforcement has been shown to be extremely effective, the use of Nano fillers may reduce the matrix's mobility and deformation by imposing a mechanical limitation. In order to create a heterogeneous mixture without causing the polymer chain segments to move, SrTiO₃ nanoparticles and other fillers will cover the spaces between polymer particles. Although the small amount of Nano filler used in this study may have helped it embed well in the polymer matrix, favorably affecting impact strength, ultra-sonication of nanoparticles may also help ensure that they are distributed correctly throughout the polymer matrix. The constraint between particles/polymer chains and the polymer chains themselves is increased by nanoparticles that form Van der Waals bonds between chains and particles.

Conclusion

The searches of this study demonstrate that the transverse strength and impact strength, surface hardness values, radiopacity, and glass transition temperature of denture base acrylic material are all improved by the addition of SrTiO₃ nanoparticles and other reinforcement materials, while a non-significant decrease in surface roughness also occurs. The most widely used PMMA-based acrylic resins in medicine and dentistry have seen substantial

improvements in recent years, both in terms of production methods and improved properties. The addition of synthetic, mineral, multifunctional monomers and natural fibres, fillers, Nano fillers, and hybrid reinforced systems, as well as the use of surface conditioning techniques, have considerably improved their physical, mechanical, and surface properties. Additionally, improved were their biocompatibility and antibacterial potency. Dentures can now be created in the lab more easily thanks to the modification of polymerization techniques. The alternative machine milling of ready-made polymerized acrylic discs with CAD/CAM techniques and 3D printing technology is a significant development in the production of dental equipment. By enhancing the mechanical and biological properties of dental acrylic resins used in dental medicine, it may be able to increase the durability and quality of dental reconstructions. In addition, less maintenance may be required, which is favourable financially. Additionally, avoiding bacterial and fungal colonization can lower the risk of developing denture stomatitis. Less allergic and adverse reactions to dentures would improve the quality of life for dental patients.

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