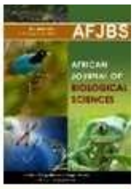
https://doi.org/10.33472/AFJBS.6.9.2024.4094-4114

AFJBS

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com



Research Paper Open Access

Biological properties of polymer based dentures. A narrative review.

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Volume 6, Issue 9, 2024

Received: 09 March 2024

Accepted: 10 April 2024

Published: 20 May 2024

doi:10.33472/AFJBS.6.9.2024.4094-4114

Abstract

An ideal denture base must have good physical and mechanical properties, biocompatibility, and esthetic properties. Different types of polymer materials have been utilized in the construction of denture bases. Polymethyl methacrylate (PMMA) is the predominant biomaterial used in the fabrication of dentures because of its advantageous characteristics, such as its ease of manipulation and coloring, satisfactory mechanical capabilities, cost effectiveness, and minimal toxicity. However, denture users still face a biological obstacle in the form of microbial dangers in the form of candidiasis incidence. The biomodifications used to denture components,more specifically denture base material to enhance their overall biological qualities as well as their physical, mechanical, structural integrity, and optical qualities are thoroughly reviewed in this paper. Furthermore basic knowledge about PMMA as a traditional denture base material and the aetiological microbial agents that cause biological harm to dentures have been investigated.

Keywords- Polymers, Denture base material, biological properties, PMMA

Introduction

Denture base materials (DBMs) are biomaterials used for fabricating the denture base [1]. The development of a full set of upper and lower dentures from human bone, which are made from the curve-molded bone layouts, coarsely cut from a bull's femur and intertwined at their furthest back points to frame a pivot, in Switzerland during the 16th century, formed the evolution of complete denture bases. Dentures composed of metals and other natural materials were first used in the 18th century; prcelain was then developed in the late 18th century [2].Because of its low density, easy maintenance and repair procedure, low cost, good physical and mechanical qualities, and optical qualities nearly identical to natural human gum, polymers especially polymethyl methacrylate (PMMA) have been widely used as a denture base material.Whereas Nemours was the first to use PMMA in powder structure, Rohm and Hass first did it in sheet design. After that, Dr. Walter Wright used PMMA as the basic material for dentures, and heused it for ten years as a prosthetic component [3]. Still, denture wearers may face a number of intraoral bacterial hazards. Known by another name, chronic erythematous candidiasis, denture stomatitis (DS) is an oral mucosal infection that usually develops in the palatal region and beneaththe dental prosthesis [4]. Denture stomatitis can present clinically as mucosal inflammation, erythema and hyperplasia, burning sensation, pain, and altered taste perception. Fungus and bacteria on the denture cause denture stomatitis. Prolonged wearing of dentures could encourage the fungus and bacteria to proliferate. As such, antibacterial qualities of the dentures are crucial toprevent the development of dangerous microorganisms. PMMA can nonetheless be made to havebetter biological qualities even if it has better mechanical ones. The resin matrix of this material has been modified by researchers to include nanoparticles and microfiller [5].Few studies had emphasized the changes made to lessen a variety of problems with the denture base that could be harmful to denture wearers. This work attempts to describe current developments on digital and conventional dentures to enhance the intraoral bioactivity and physical and mechanical reaction on denture base area.

Materials and Method

A comprehensive search was conducted on electronic databases using the following keywords— "biology denture," "bioactivity denture," "modification denture,"and "digital denture biology"— dated upto February 28, 2024, including PubMed/Medline, and Web of Science. After selecting English- language publications, the papers underwent additional screening to determine their applicability to this review. Published between about five years ago and the present (2017–2024). Mostly in vitro research and/or analytical experimental research papers made up the publications chosen. The published chosen papers had to have a main result with biological features. Articles with casestudies or maxillofacial prosthesis, such as obturators were excluded.

Discussion

PMMA (Polymethyl Methacrylate) is a synthetic resin polymer formed by polymerization of methyl methacrylate (C5O2H8)to polymethylmethacrylate (C5O2H8)n, and it is fundamentally an essence obtained from an ester of methacrylic molecule (CH2=C[CH3]CO2H). Usually, polymerization occurs in the presence of an initiator and is triggered chemically or by other possible sources like heat and light. There are more groups within the manufacture and activation of the PMMA material used for dentures [6]. Based on the different kinds of polymerization activators—heat, light, or cold cures—the denture base polymers can be categorized. When the powder containing PMMA is combined with benzoyl peroxide initiator, a plasticizer (dibutyl phthalate), and liquid made of methyl methacrylate (MMA) monomer and ethylene glycol dimethacrylate, which functions as a cross linking agent with hydroquinone as an inhibitor, the polymerizarion reaction in the heat cured type of PMMA starts. Theoretically, heat initiates the polymerization heat curing process. When the monomer(MMA) and polymer (PMMA) are converted into a mixture and heated in a water bath to activate the initiator to dissociate into

carbon dioxide (CO2) and produce free radicals, that is the chemical reaction in this acrylic resin polymerization process [7]. These elements, meantime, included a photo initiator system, a urethane dimethacrylate matrix, and fillers made of microfine silica and acrylic copolymer. Same visible light source used for cold curing light as activated composite also activates the photo initiator. Soft sheets already mixed for final polymerization were supplied by a special high intensity light source. As such, those who are allergic to methyl methacrylate monomer can substitute the light activated denture base material.

Cold cure PMMA type does not need thermal energy since it contains a tertiary amine initiator, like as para-toluidine, which starts the breakdown of benzoyl peroxide. The tertiary amine of PMMA (polymer) + benzoyl peroxide (initiator) and MMA (monomer) + dimethyl-para-toludin is activated to convert the resin from monomer (MMA) to polymer (PMMA). Benzoyl peroxide is equivalent to two water and functions as an initiator to interact with the monomer in the initial stage of MMA monomer suspension of polymerization [8]. Additionally useful for producing smooth, consistently sized spherical microparticles is a soluble water-stabilizer. Free radicals are thereby liberated, which facilitates polymerization. The main issues in the strength characteristics of this material are still incomplete polymerization and insufficient adaptability, even though a high degree of polymerization produces solid physical characteristics. Weak link strength and costly materials for the inactivation equipment used in this polymerization process are theconstraints of the product yield [9]. Because of its better qualities, PMMA has been used as a denture predominantly in recent decades. Still, the release of residual methyl methacrylate monomer—a free monomer when made by heat polymerization—is the primary worry for PMMA in the production of traditional dentures. Even though most recent research indicates that PMMA monomer leaching (about 5.4 weight percent) is a rare occurrence, this monomer leaching that is released from the PMMA material can also cause allergic reactions, such as mucosal ulceration, oedema, and denture stomatitis, which are exacerbated by the adhesion of bacteria like Candida albicans and Staphylococcus aureus [10]. Because of errors introduced during the manufacturing process of different procedures, such as separating media application, post-dewaxing operation, consis- tent polymer to monomer ratio, trial closure method, and curing cycle leads to the porosity of the denture, this material is also susceptible to change in dimensional stability. The mechanical and aesthetic characteristics of thematerial deteriorate physically when porosity is more than 11% of the original composition, creating uneven surfaces for the microorganism reservoir, such Candida albicans.

Typical Microbiological Problems with PMMA in Conventional Dentures Retainer

Stomatitis

There exist three primary forms of denture stomatitis. Localized areas of inflammation are present in denture stomatitis Type 1, which can be brought on by trauma or an overly tight denture. The most common form of denture stomatitis in long-wearing dentures, type 2, manifests as widespread erythema covering the denture-bearing region, while type 3, also referred to as inflammatory papillary hyperplasia, typically affects the alveolar ridges or the hard palate [11]. Denture stomatitis has several prevalent causes. Certain species of Candida albicans. is considered to be the primary cause of 90% of instances of denture stomatitis and one of the primary contributing causes to the aetiology of DS. Several species of bacteria, such as Bacteroides sp., Fusobacterium sp., Streptococcus sp. is capable of involvement [12]. Candida may also act as an opportunistic infection and changes position when the immunological balance between the host and the fungus changes from commensal to parasite [13]. List of Candida species. must initially attach to various host cells, either directly or indirectly through the assistance of other microorganisms or immobilized adhesins like integrins or cadherins [14]. Hyphal Wall Protein (HWP1), Amyotrophic Lateral Sclerosis type 1–7 (ALS1–7), and other adherence proteins help yeast cells stick to the surface of their hosts. Hydrophobicity affects the way that ALS proteins interact with abiotic objects and helps biofilms to form, for instance, on prosthetic devices. After thereafter, cells will actively enter the mouth cavity and encourage endocytosis to enter the tissue. Before bursting the cellular barriers that will break down the membrane and surface components of the invading cell, albicans secretes a variety of hydrolytic enzymes, such as aspartic proteinases, a phospholipase, and a lipase. Since secreted aspartic proteinases break down immunoglobulin G (IgG) heavy chains, C3 protein, collagen, and fibronectin, they allow the invasion of the host cell and suppress the host immune system. Thus, these results have validated the tissue irritation brought on by the insufficient defense systems of the host. Furthermore, the risk of developing this oral mucosal disease in patients who wear dentures ranges from 36.7% to 65% [15,16]. This is because of the existence of ideal Candida growth conditions that allow the fungi to colonize the acrylic resin creating favorable conditions for adhesion and proliferation [12]. Risk factors for this condition include denture age, immunocompromised patients with systemic chronic diseases like poorly controlled diabetes mellitus, damaging habits like smoking, and continuous and repetitive denture use without periodic tissue rest. Other risk factors include damage on the abutment and residual tooth, reduced salivary flow due to chronic diseases like Sjogren Syndrome or certain medications. Moreover, the rough and rigid fitting surface of the denture can serve as a reservoir, promote the attachment of bacteria to the denture, and promote the development of biofilms. Denture stomatitis lesions are definitely linked to poor denture cleanliness, which promotes the growth of harmful bacteria in tooth plaque on denture fitting surfaces. Candida can build up a biofilm on the mucosa beneath a denture if it is worn all the time, particularly at night. Candida grows in an essentially anaerobic environment produced by a lower pH. Because saliva cannot clean the area where dentures are worn, dangerous bacteria proliferate there. Furthermore supporting the development of harmful bacteria in the dental plaque on the denture fitting surfaces was poor denture cleanliness. Poor denture care and a bad fit are definitely related because of inflammation in the denture-bearing region [17]. Denture stomatitis can be treated in a number of ways. One of them is to reduce palatal irritation by utilizing antifungal drugs, which come in a variety of forms, such as application (Amphotericin B, Nystatin, Econazole) [18]; this effect is increased if denture care is improved. Patient should then be taught the proper way to clean their dentures. Thorough brushing of the denture together with a non-abrasive proprietary paste, which should be done after every meal, are effective active techniques for cleaning dentures. Moreover, to get rid of bacterial plaque on dentures, it is also recommended to soak them in warm soapy water or 0.1% aqueous chlorhexidine every night [19].

One Candida species that may grow on a variety of surfaces is Candida albicans. The most often isolated Candida species occurring in denture stomatitis presentations is by far Candida albicans, followed by Candida glabrata [17]. Candida is made up of essential components in resistance to the host clearance systems in the oral cavity, which act as protective reservoirs and keep Candida from being washed away by saliva or dislodgement forces. Candida can bind with oral mucosa. One of the reasons this yeast is pathogenic is because it can attach to mucosal cells, change from a single cell to a filamentous form, secrete enzymes like phospholipase and aspartyl proteinase, and create biofilms [20]. On the other hand, albicans is readily drawn to the acrylic resin used to create dentures, and this resin has certain characteristics, including hydrophobicity, that promote adhesion as a crucial step in the formation of biofilms [21].

Staphylococcus aureus

Based on its moniker "Aureus," Staphylococcus aureus is a gram-positive bacteria having golden color properties. In addition, it can tolerate high salt, low pH, and high temperatures and dwells in a facultative anaerobe habitat. Moreover, β-lactamase is the most common of the virulence agents that Staphylococcus aureus produces. Dental prosthesis are one of the many oral surfaces that Staphylococcus aureus can cling to and is not shedding. Through their production of toxins, such exfoliative toxins A and B, which can dissolute the epidermal desmosome and cause fine sheets of skin to peel off and expose the wet red skin beneath, these bacteria can also cause illnesses. A couple of studies have revealed that Staphylococcus aureus colonies from the hard palate are grouped in tiny clusters that are taken from the denture stomatitis location. Several assays and PCR amplification of Nuc and Coa genes such as catalase-positive, Pastorex Staph Plus positive, and clumping factor-positive oxidase-negative identify these colonies as Staphylococcus aureus. After 23 hours of incubation, a delayed coagulase reaction was seen in the tube coagulase test. Furthermore, several research revealed that although Staphylococcus aureus from denture wearers activated monocytes more than those from non-wearers, they were less likely to phagocytosis, indicating that the bacteria may have enhanced virulence characteristics [22]. We can therefore conclude that Staphylococcus aureus may also contribute to the occurrence of denture stomatitis due to its adherence ability to prosthetic materials and its strong virulence factor because recent evidence suggests that Staphylococcus aureus strains are equally and frequently isolated from older persons presenting with denture stomatitis as asymptomatic denture wearers [19,23].

Mutans Streptococcus

A typical bacteria on denture surfaces, Streptococcus mutans may occupy the binding sites and encourage yeast attachment if cultured with Candida albicans the same time. In vitro adhesion mechanisms of S. Mutans and the C. Albicans can help to clarify how these creatures behave in tooth plaque. In a combined culture, these microorganisms are usually thought to interact mutually [24]. Traditionally, oral biofilm formation and unique adherence mechanisms that can result in candidiasis resistance to antifungal therapeutic agents are thought to begin with the adherence and maturation of strep mutans. The capacity of yeast to agglutinate with bacteria in complicated biofilms, such as those seen in the oral cavity, can be mediated by species interaction inside the biofilm as well as external variables including saliva, oral hygiene, and exposure to antimicrobial agents. In-vitro data demonstrated that, in spite of the Candida–bacteria relationship, new research has looked into the S. Patients with candidiasis or illnesses associated to yeast can also benefit from mutans species [25].

Nucleated fusobacterium

In the oral cavity, plaque and biofilm are produced in part by the Gram-negative anaerobe Fusobacterium nucleatum. F. Being able to come into direct touch with both Gram-positive and Gram-negative species, nucleatum is a well-known "bridging" organism needed for the orderly sequence of colonization events in oral polymicrobial communities. Early commensal colonizers and late invaders, mostly periodontal infections, can be connected by it. It thus becomes essential to the genus succession in oral polymicrobial communities. Fusobacteria can interact with bacteria and establish direct physical associations with eukaryotic microbes, such fungus. The coherent of F. Candida albicans and nucleatum are well known. It has been connected to Candida albicans colonizing the oral cavity, which according to some researchers was the primary bacterium responsible for denture stomatitis. Such interactions between kingdoms might be very important to C. albicans survive as a component of the host's microorganisms and, in certain situations, help to progress polymicrobial illnesses [26]. Thus, novel targeted treatments to prevent adhesion should be made easier with a greater knowledge of the interacting biological components. In the polymicrobial pathogenesis involving these two species, this mechanism might be quite important.

Evolution of Digital Dentures

Fixed, implanted, and detachable prosthesis are being designed and manufactured in large part using computer-aided design and manufacturing (CAD-CAM) technologies. The expansion of digital manufacturing techniques in dentistry has been facilitated by the quick technological progress in artificial intelligence, data collection, quick prototyping, and digital imaging such cone beam computed tomography (CBCT). Dentures made with CAD-CAM technology were shown to be the most accurate, less porous, and produced quickly [27]. High quality 3D printers and scanners combined with CAD-CAM technology in digital dentistry can enhance the fit, appearance, and useful components of dentures while cutting labor and expenses, hence boosting production outputs and efficiency. Polymers would be especiallyinteresting in digital dentures because of their easy production and desired qualities. With the capacity to create and design dentures digitally, the whole spectrum of biomedical polymers becomes available for use as the material of preference in digital dentistry. Significant progress for detachable prosthesis is provided by the development of novel polymer materials with higher biocompatibility, durability, flexibility, cosmetic appeal, and affordability [27,28]. Roughness is one factor that affects both the color stability of the denture materials and themicrobial colonization on denture surfaces [29]. The present study shows that the surface roughness of milled resins and fast prototyped resins is similar. A research indicates that 3D- printed dentures have a rougher surface area than traditional dentures. This surface element is necessary since it makes bacterial adhesions easier. Rough surfaces could promote the development of bacteria [30].Often constructed of poly-methyl methacrylate (PMMA), a porous polymer that is more susceptible to the formation of microbial biofilms than traditional dentures [31], microbial adhesion is the first step in the formation of a biofilm. The surface-bound salivary proteins and mucins absorbing to the pellicle regulates it [32].

Modern changes in dentire base material

It is known that certain materials enhance the general mechanical characteristics of the materials and lessen bacterial colonization. Materials that have helped to improve the denture, particularly biological properties, include Titanium Dioxide (TiO2), Graphene-Silver nanoparticles (G-Ag NP), Silver nanoparticles (NAg), graphene, 2-methacryloyloxyethyl phosphorylcholine (MPC) and dimethylaminohexadecyl methacry- late (DMAHDM), Surface Pre-reacted Glass-ionomer (S-PRG), food preservatives, in- cluding zinc oxide, potassium sorbate, sodium metabisulfite, nano-silver loaded zirco- nium phosphate, Phytoncide, Silicon Dioxide nanoparticles (SiO2 NP), quaternized N, N-dimethylaminoethyl methacrylate (DMAEMA), and also probiotics [33]. Titanium Dioxide (TiO2) is one of the nanoparticles whose strength of dentures has been demonstrated. TiO2 nanoparticles at weights of 0.2 percent, 0.4 percent, 0.6 percent, 1 percent, and 2.5 percent were added to PMMA in turn to produce the composite mixture. Few of the microorganisms it has been demonstrated to be active against include fungus, gram-positive and gram-negative bacteria, and other microbes. Studies further demonstrated its environmental friendliness and antimicrobial action. Furthermore, the apparent great stability, catalytic function, availability, white color, efficiency, and low cost of TiO2 have made it increasingly well-known recently. Chemical inert, non-toxic, and corrosion-resistant is TiO2 [34]. One material that helps improve 3D printed dentures is graphene-Ag nanoparticles (G-Ag NP). Graphene silver nanoparticles (G-Ag Np) were composited via radio-frequency chemical vapour deposition (RF-CCVD). Graphene and silver nanoparticles added to PMMA enhanced its mechanical and physical properties. Silver fillings have been shown to be antibacterial. Further research is necessary to determine if the added fillers or the greater ratio of free monomers are responsible for the antibacterial action [35].The manufacture of silver nanoparticles (NAg) solution and its combination with acrylic acid andmethyl methyacrylate (MMA) monomer produced a novel type of NAg solution (NS)/polymer methyl methacrylate denture base speci- mens (NS/PMMA). Easily available is a commonly utilized type of antimicrobial nanomaterial that has shown a wide spectrum, high efficiency, strong antibacterial activity, and comparatively acceptable biocompatibility. Furthermore, it is a cheap and easy technique that has a strong potential to evolve into an antibacterial therapy for removable partial or full dentures. Undoubtedly, it is a suitable material that can be applied to the senior population [36]. An alternative material that has been used to enhance the qualities of the denture is called nano- graphene (nGO). The powder of nanographene nanoparticles (nGO) was cleaned and sterilized by washing it in 70% ethanol. Chemically activated PMMA materials were selected to avoid thermal degradation of the nGO during heat-induced polymerization. To PMMA powder, nGO was added in weight-relative amounts of 0.25g, 0.5g, 1.0g, or 2.0g. Without compromising mechanical properties, it employs carbon-based nanoparticles to offer long-lasting, sustained antimicrobial- adhesive properties. Novel methods such functionalizing nGO with PEG, salinization, or carboxyl group to address the uneven dispersion of nGO in composite should be included in future research [37]. MPC (2-methacryloyloxyethyl phosphorylcholine) is another protein repellent that impedes C. Added to other materials to prevent albicans from sticking to denture surfaces, PMMA denture base materials were shown to have certain advantages. The contact-killing approach is also used to synthesise dimethylaminohexadecyl methacry-late (DMAHDM). A ruptured cell and cytoplasmic leakage are the outcomes of these positively charged materials coming into touch with a negatively charged cell membrane. These elements working together result in fewer biofilm colony-forming units [38]. Zinc oxide, potassium sorbate, and sodium metabi-sulfite are among the food preservatives that can be added to the PMMA denture base. ZnO causes reactive oxygen species (ROS) that in turn cause cell damage and apoptosis. By building up protons inside of the microbial cells, two weak acid preservatives, potassium sorbate and sodium metabisulfite (PS and SM), can halt biological metabolism; but, PS and SM also result in lipid peroxidation, which harms the cell membrane. Moreover, the sulfur-containing chemical SM has been linked to the emission of sulphur dioxide molecules. These compounds have the ability to break disulfidenconnections in protein structures, which kills enzymes and damages cells. It has thus been shown that these actions of food preservatives on the denture base materials also have antibacterial properties [39].By weakening the cell wall, causing bacterial self-degradation by the breakdown of cell membranes, or interfering with the respiratory metabolism of bacteria, phytoncide possessed antibacterial effects. Thus, the phytoncides produced by phenolic substances could be able to lessen microbial activity. Moreover, a large number of the secondary metabolites produced by plants stress various bacteria. This stress will affect microbes, and it is thought to be a plant defensemechanism. One disorder that affects ecological systems is allelopathy [40].The additional coating of film produced by SiO2 nanoparticles also helps to enhance PMMA properties by preventing bacterial attachment to the denture base and having a self-cleaning effect.In hierarchical systems of the micro-nano size, the water molecules are very polar. Water easily rolls off the sample surface because of its strong adsorption action on debris that is clinging to thesurface. From another perspective, titanium dioxide acts as a photocatalyst that will disrupt the equilibrium of essential oils including K+, Na+, Ca2+, and Mg2+ by producing reactive oxygen species, which will damage the bacterial cell membrane and cause lipid peroxidation and cell death[41,42]. However, one of the hardest parts of modifying pure materials is still to enhance their basic characteristics without sacrificing other features. For instance, while adding fibers or nanoparticles can boost the strength of PMMA, doing so can also exacerbate biocompatibility problems by allowing breakdown products to leach into the oral cavity or damage its appearance, including color or transparency. Though the results of the present laboratory modification of PMMA are promising, cautious interpretations and analysis are still necessary before employing modified PMMA materials for clinical applications. Most of the biocompatibility and in vivo performance of changed materials are still debatable and need more clinical research, most likely in human trials. Further study should concentrate on the molecular interactions of changed materials, the assessment of different attributes in accordance with American Dental Association standards, and clinical performance in either in vivo clinical investigations or simulated oral environments.

Conclusion

Many materials and techniques have been developed to enhance the biological characteristics, particularly the biocompatibility and biofunctionalization of the denture base. A particular substrate should ideally be added to the denture base to enhance its biological activity in addition to its general physical, mechanical, and visual qualities. Still, as was already discussed, the possible detrimental impact on mechanical characteristics upon enhancing the biological activities following the incorporation of particular substrates, such as Quaternized N, N-dimethylaminoethyl methacrylate (DMAEMA), was carefully taken into account. More inorganic and organic components should be added to the denture material, especially the denture base material, to improve its characteristics on a larger variety of bacterial and fungal strains. Future studies must also stress a thorough investigation, especially on characterisation and mechanical properties.

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