DENTURE BASE POLYMERS EVOLUTION AND IMPROVEMENTS-A LITERATURE REVIEW

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ABSTRACT
The improvement of the basic properties of dental restorative materials, such as their mechanical, physical, aesthetic, and bonding properties, has been dramatic and the current materials on the market show excellent clinical performance. This review article compiles the characteristics of resin based dentures materials and the efforts made in order to improve the main features and to point out future perspectives.

Key words: denture base, PMMA, polymers, dental materials.

INTRODUCTION
The field of prosthetic dentistry is null without dental materials. Both are inextricably connected to each other since they have evolved. Prosthodontists are the ones who encounter with multitudinous materials [1,2]

In recent years, demand of biomedical materials have been increased due to increased and productive interaction of interdisciplinary fields of material science and molecular biology. Materials used in dentistry have evolved a lot with such interaction. Development of dental materials with reduced polymerization shrinkage (PS) and better depth of cure or degree of conversion along with improved mechanical properties and aesthetic are of the prime interests for the researchers of dentistry and material scientists [3].

Poly (methyl methacrylate) (PMMA) is the most commonly used denture base material for the past sixty years. The numerous advantages of poly methyl methacrylate (PMMA) make it the most dominant polymer used as denture base material. The ease of processing, low cost, light weight, stability in the oral cavity, and aesthetic properties are of these advantages. It is the combination of various desirable properties of PMMA resin that accounts for the universal consumption though its properties are not ideal in every aspect. The limitations of heat-cured PMMA resin with respect to strength, peculiarly under impact and fatigue conditions, were investigated by several researchers [3,4]

As mentioned, PMMA is the most predominant polymer based material for dentures. However, its mechanical and surface properties are low [5].

Addition of any material to improve the antimicrobial properties of the PMMA should not have an adverse effect on the mechanical properties. In reverse, it is highly
preferred to add a material that will improve both biological and mechanical properties [3,4,5].

Polymethyl methacrylate (PMMA) has been widely utilized in denture base polymers, which are multiphase polymers made of polymethyl(methacrylate) (PMMA) beads and monomers of methyl methacrylate and cross-linking agent. The crosslinking agent is typically dimethacrylate but methacrylated dendrimers have also been tested [6].

However, the acrylic resin denture base polymer has not fulfilled all the requirements in terms of optimum mechanical properties [7] due to its brittle nature under its glass transition temperature of approximately 110°C [2], and its susceptibility to cyclic loading. For this reason, fatigue fracture of dentures is a common clinical manifestation [8].

Thus, numerous investigations have been conducted to improve the mechanical properties of denture bases since denture base polymers should possess adequate strength to resist the various forces occurring in the oral environment [5,8].

Fiber-reinforced composites (FRC) have been introduced [9] to overcome the problem of denture fractures by improving the mechanical properties of the denture base polymer. Partial fiber reinforcements, namely accurate placement of a relatively small quantity of fibers in the denture base polymer, have been employed to strengthen dentures both during repair and in the manufacturing process [5,6].

The types of fibers that have been used to reinforce denture base polymers include aramid fibers [10], carbon/graphite fibers, ultra-high molecular weight polyethylene (UHMWP) fibers and glass fibers [5,6,11,12].

Although UHMWP fibers have relatively good mechanical properties, there are reports that poor adhesion of the fibers to the polymer matrix, even with the aid of plasma treatment, does not considerably increase the mechanical properties of the denture base polymer [13].

One significant factor affecting the strength of denture base polymers is the composition of the polymer. Most PMMA resin systems include powder and liquid components. The powder consists of prepolymerized beads of PMMA and a small amount of benzoyl peroxide as an initiator. Crosslinking agents are added to the monomer liquid [14].

The crosslinking agent forms bridges between the PMMA polymer chains and increases the molecular weight (MW), mechanical strength and solvent resistance. A new alternative crosslinking agent for dental polymers is methacrylated dendrimer monomer, which has the potential to improve the properties [15].

As soon as the powder and liquid are mixed, the MMA monomer liquid with crosslinking agent diffuses into the PMMA beads and dissolves the outer surface of the polymer beads, causing them to swell. There is also an intermediate layer between the polymer beads and the crosslinked polymer matrix, called the “semi-IPN (interpenetrating polymer network)” layer [16].

Denture base polymer is composed of three phases: polymer matrix, IPN, and polymer beads; thus, the mechanical properties of the polymer are affected by the ratios of these phases. In general, the higher the molecular weight, the more difficult it is to distort the polymer material, so properties such as rigidity, strength and the melting temperature increase. Improvements in the mechanical properties of the denture base polymer would be desirable to meet the demands of clinical use [17].

The recently introduced option of computer-aided design and computer-aided manufactured (CAD/CAM) removable dentures [10–14] definitely addresses this demand, as it has fundamentally changed the manufacturing process. Instead of manually mixing the resin powder and liquid and then submitting the immersion to an arbitrarily chosen curing protocol, the poly(methyl methacrylate) (PMMA) resin blocks for CAD/CAM denture bases are industrially fabricated [15,16] and cured under “great heat and pressure” [17,18].

Therefore, it has been assumed that
the CAD/CAM denture base resins are highly condensed and have fewer micro-porosities [17]. This, in consequence, would mean that CAD/CAM denture base resins could have superior mechanical properties [8], which is probably why some of the CAD/CAM denture manufacturers advertise that their products have a very low minimum material thickness [19].

Also, the dentures installation in the oral cavity changes the environment and leads the way for the accumulation of biofilms on the prosthetic device. Preventing bacterial biofilm formation is a major challenge in dentistry. Biofilms are collections of microbes that attach to hard tissue. These microbes produce excessive extracellular polymeric substances (EPS) that protect them from their environment and antibiotics, thereby making them antibiotic resistant [18,19]. Nanotechnology and polymeric nanomaterials have been used to prevent bacterial adhesion and biofilm formation [20,21].

The combination of nanoparticles (NPs) and antibiotics enhances antibiofilm activity. Microbes adhere quite strongly to denture base materials as a result of the microporosity of the denture surface [5] Candida adheres directly or through a layer of denture plaque to denture base acrylic resin. Without this adherence, microorganisms would be removed from the oral cavity when food is being swallowed.[22]

Although C. albicans has been found to be the predominant oral yeast isolated from dentures, Candida dubliniensis, Candida parapsilosis, Candida krusei, and Candida tropicalis have also been isolated. To counter this problematic association between dental resins and dental plaque, many studies have focused on endowing resin-based dental materials with antibacterial properties [7,8].

Epidemiological studies report that approximately 70% of removable denture wearers suffer from denture stomatitis. C. albicans adhesion and biofilm formation are regarded as essential prerequisites for denture stomatitis. Since the introduction of crosslinking thermoset monomers in dentistry by Bowen [3], cross-linking dimethacrylate monomers became available also for monomer liquids of denture base resins and, thus, in multiphase denture base polymers. This can be considered the start of the use of IPN-like structures of various kinds in dentistry.

By definition, an IPN is a combination of two or more polymers in network form that are synthesized in juxtaposition [3].

IPNs do not interpenetrate by chemical reactions on a molecular scale, but are composed of finely divided phases of 5–10 nm. IPNs differ from polymer blends which are less homogeneous in structure. They differ from copolymers which are based on chemical reactions of monomers and polymer [1.5].

Currently, the IPN-like structures can be found in nanostructures in denture base polymers, denture teeth, fibre-reinforced composites (FRCs), and very recently, in the restorative composite resins[4,5].

Nano silver has demonstrated antifungal activity and inhibited C. albicans biofilm formation. Antifungal activity and an inhibitory effect on adhesion and biofilm formation by denture base resin containing nano silver have been demonstrated [9,10].

A few studies evaluated the antimicrobial activity of acrylic resins containing different percentages of silver and zinc zeolite. They found that the addition of 2.5% silver and zinc zeolite to the materials resulted in antimicrobial activity against all strains. However, the flexural strength and impact strength of the acrylic resins decreased significantly with the addition of zeolite [11-13].

Currently, antibacterial agents incorporated into dental materials are classified into organic agents (such as quaternary ammonium salts, 12-methacryloyloxydodecyl-pyridinium-bromide [MDPB],quaternary phosphonium salts and natural products) and inorganic agents (such as silver and titanium dioxide [TiO(2)]).[14]

Studies have reported that the surface roughness of a denture should not exceed 0.2 μm [15]. Although there is a direct relation between surface roughness and candida
adhesion (increased roughness increases candida adhesion), the reduction in candida count confirms the antifungal properties of TiO2NP.

TiO2NP has proved to have antimicrobial properties. Moreover, it is a cheap biocompatible material, chemically stable, free of toxicity, resistant to corrosion with high strength, and high refractive index [8, 15, 16].

Furthermore, the literature showed that even the slight addition of TiO2NP reinforcing agent to a polymeric material affects the electrical, optical, chemical, and physical properties of the resulting hybrid material [9, 13]. TiO2NP have been found effective against a wide range of microorganisms including gram-positive and gram-negative bacteria, fungi, and viruses [11, 17, 18].

The antimicrobial effect could be attributed to the surface properties and structure of the nanoparticles, including nanocrystalline TiO2, hydrophilic surface effect, infrared reflectivity and noncontact antimicrobial activity. Therefore, TiO2NP have been recommended as filler in polymeric materials [14]. Research to improve upon existing nanomaterials is still ongoing with emphasis on efficiency. Although the science behind nanotechnology is intriguing, the lack of long-term evidence addressing their clinical performance restricts their wide clinical use.

Many dental diseases are caused by the oral microbiome, and restorative materials with antimicrobial effects could be useful for preventing such infectious diseases.

A conventional approach to provide dental restorative materials with infection control abilities is to incorporate water-soluble antimicrobials and enable their release in a wet environment. However, the duration of the antimicrobial effects produced using this method is limited to a short period and continuous delivery of the agents is not possible.

A better approach is to fabricate such acrylic dentures which may act as DRDs (Drug releasing devices) from which antifungal drugs elute and inhibit microbial growth. Most commonly used agents for such purposes are chlorhexidine acetate and digluconate which are commonly used as antiseptic mouthwash due to its broad-spectrum antimicrobial activity [20, 21].

However, when used as a mouthwash, most of the agents are removed from the mouth during the first hour, due to the diluting effect of the saliva.

Their incorporation in denture base resins is a novel approach. Other drugs like Fluconazole and Miconazole in specified concentrations and hydrocortisone sodium succinate (HSS) are also mentioned in literature as Drug delivery devices for treatment of recurrent ulcers.

Drug-delivery is a relatively new arena for denture bases and apart from antifungals, sialagogues incorporation for the treatment of xerostomia conditions is also a newer area for studies. Similarly drug based delivery in nylon and polyamide dentures also needs to be explored [22].

However, the incorporation of active agents directly into dental restorative materials has several drawbacks.

First, control of the release kinetics is difficult. To attain clinical effectiveness, it is important to have appropriate release of the agent to suit the environment in which the materials are used.

Secondly, as the release of the agent occurs, the materials become porous and their mechanical properties decrease over time. Thirdly, in the case of resinous materials, the incorporation of additives may compromise the curing of resins and hamper their integrity for permanent restoration.

These are critical problems since dental restorative materials used to artificially recover lost tissue need to have high mechanical properties, physical and chemical stability, or to strongly bond to adherend.

Assessment of more number of performance characteristics with varying input parameters for the development of resin based dental materials can be studied. Various factors affecting polymerization are of key importance.

Further investigation may be carried
out to assess the effect of different input parameters of polymerization process to achieve the desired physical, thermo-mechanical and wear properties of denture base polymers [19,20,21].

CONCLUSIONS

Functionalized dental materials have been evolved in past ten years but longevity of specific function is needed to be explored in detail. So, it can be concluded that there is vast space for further research in terms of appropriate resin material, filler particles and their surface modifications, wear behaviour in varying oral environment and specific functionality of dental materials such as antimicrobial properties, self-healing properties, remineralization properties etc.

REFERENCES