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RESEARCH ARTICLE

NEW CONCEPTS IN DENTURE BASE MATERIAL

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ABSTRACT

The use of denture base resin has revolutionized the dental material sciences ever since their discovery. Many prostheses and implants made from polymers have been in use for the last three decades and there is a continuous search for more biocompatible and stronger polymer prosthetic materials. Resins have been reinforced using different materials to improve strength. This paper reviews acrylic denture base resin enhancement during the past few decades. Specific attention is given to the effect of fiber, filler, and nanofiller addition on poly (methyl methacrylate) (PMMA) properties.

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INTRODUCTION

The loss of teeth by accident or disease has plagued mankind throughout the ages. In order to restore a degree of function and appearance, it has been necessary always to adapt contemporary materials to dental applications as they are available in one period of history. As civilization has progressed there has been continued refinement of the materials available for dental practice. As time passed and civilization advanced with the development of biological, chemical and physical sciences, there occurred a slow but steady increase in both the quantity and quality of useful materials available for dental prostheses. The material should be biological compatible, readily available, reasonably inexpensive and simple to manipulate with a readily controlled technical procedure, to develop a prosthesis that is functionally effective and pleasing in appearance (Khindria, 2009). Over the years, a variety of materials has been used for the fabrication of the denture bases. Polymethyl methacrylate (PMMA) is the most commonly used denture base resin as they have less cost, easy manipulation, easy construction method, and easiness of repair as compared to other materials available for fabrication of denture. But it has certain drawbacks like residual monomer allergy, poor mechanical strength, low fatigue strength, brittle on impact, poor conductors of heat, low hardness, high coefficient of thermal expansion, thermal shrinkage, poor color stability of self-cured resins, porosity, crazing, war page, poor adhesion to metal and porcelain and requirement of mechanical retention. Thus, to overcome these drawbacks, there has been much new advancement in the field of acrylics. Resins have been reinforced using different materials to improve strength. The hypoallergenic resins overcome the problems of monomer allergy. Other physical properties have also been improved by using different additives in resins (Nandal, 2013). In recent years, new generation polyamide thermoplastic resins and commonly used in the production of removable dentures (Porwal, 2017). No matter what kind of denture base material we are using, denture care is indispensable for oral health, otherwise denture become unsanitary and undesirable effects are expected such as bad breath, unpleasant staining and biofilm, calculus accumulation on the denture which can lead to denture stomatitis, angular cheilitis and poor oral health (Salman, 2011). Contamination of prostheses can provide a source of cross contamination between patient and dental personnel. Denture plaque is also a major factor in etiology of opportunistic infections and respiratory tract infection by aspiration in elderly patients (Machado, 2009).

DISCUSSION

- Reinforced resins
- High impact resins

- Fiber-reinforced
- Hypoallergenic resins
- Resins with modified chemical structure
- Thermoplastic resins
- Enigma gum toning in denture bases
- Nanofillers

Reinforced Resins

High impact resin: Rubber reinforced (butadiene-styrene polymethyl methacrylate). Rubber particles grafted to MMA for better bond with PMMA. It has greater impact strength and fatigue properties, indicated for patients who drop their dentures repeatedly e.g. parkinsonism, senility. Available as powder-liquid system and processing is same as heat-cure resins. E.g Lucitone 199 (Figure 1), D.P.I Tuff, fricke-high impact. Iimpact strength of D.P.I Tuff is more than Lucitone 199 (Kostoulas et al., 2006).

Fiber reinforced resins: Fiber reinforcement result in a 1000% strength increase over non-reinforced (if there is proper bonding). It was reinforced with embedded metal forms. Fibers have been used in three forms, namely, continuous parallel, chopped and woven. Glass Fibers- GFs were tested as a reinforcement for denture base PMMA as early as the 1960s. Continuous parallel fibers provide high strength and stiffness in one direction (anisotropic) while randomly oriented fibers provide similar properties in all directions (isotropic properties). Continuous fibers provide superior reinforcement over chopped fibres but placing continuous fibers at weak parts of denture is difficult and there is formation of voids inside fiber-polymer matrix system due to poor impregnation of fibers by resin and polymerization shrinkage, so chopped fibers mixed with denture base acrylic resin enhance isotropic mechanical properties. Glass fiber reinforcement has been found to significantly increase the flexural strength, impact strength, toughness, and Vickers hardness of acrylic resin. Also, a significant reduction in deformation of the denture base to less than 1% deformation was found. Preimpregnated and silane [3-(Trimethoxysilyl) propyl methacrylate (TMSPM)]-treated glass fiber also increased the flexural strength and impact strength of acrylic resin. Silanized glass fiber was found to be biocompatible when added to heat-cured and light-cured resins. Moreover, fiber-reinforced nanopigmented PMMA showed reduced porosity and Candida albicans adherence (Abdulrazzaq Naji, 2018).

E-glass fibers: Each strand of this E-glass is computer impregnated with a PMMA (porous polymer) and silane coupler that allows dissoloution bonding to acrylic. (e.g. Preat Perma Fiber)

Advantages: Available in two forms (mesh and fiber) and are translucent providing esthetics. Because of glass fiber bonding, they also have more strength.

Metal fiber reinforced: Not widely used because unesthetic, expensive, poor adhesion between wire and acrylic resin and metal being prone to corrosion. Using full lengths of metal fibers offers the best reinforcement.

Carbon / graphite fiber reinforced: Carbon fibers (65-70 mm length, 5% by weight and treated with silane coupling agent) are placed during packing. Carbon Graphite fibres are available as-chopped, continuous, woven, braided and tubular but tubes of braided fibres provide a more even distribution of reinforcement, high filler loading and easy handling because fibre bundles at different angles are advantageous when multi-axial forces are present (e.g. in implant supported prosthesis) Carbon-graphite fibers are anisotropic and provide greatest reinforcement of denture base resins in terms of flexural strength and bending properties when placed longitudinally (perpendicular to applied forces) but because of difficulty encountered in placing the fibres centrally fibres are placed randomly oriented.2 angles are advantageous when multi-axial forces are present(e.g. in implant supported prosthesis). [8]

Advantages: Increases flexural strength, impact strength, prevents fatigue and strengthens the resin.

Disadvantages: Unesthetic because of black colour but this can be covered by an opaquer. The polishing is difficult and also weakens the finished prosthesis. In addition, there is problem of lateral spreading of fibers during pressing.

Aramid fiber reinforced: Aramid fiber (AF) is the generic name for aromatic polyamide fibers, which arc more commonly called kevlar fibers, after the first commercially available AF produced by DuPont (Kostoulas, 2008). Aramid fiber reinforcement increases the strength but again they are unesthetic and difficult to polish so limited to locations where aesthetics is not important. Aramid is a generic term for wholly aromatic fibres. These fibres are resistant to chemicals, are thermally stable, and have a high mechanical stability, melting point, and glass transitional temperature. They also have pleated structure that makes aramid weak as far as flexural, compression, and abrasion behaviour are concerned. This explains why aramid fibre-reinforced demonstrate a lower flexural strength than PMMA reinforced with glass fibre. Studies conducted by Berrong et al (1990) have shown to significantly increase the impact strength and the modulus of elasticity of the resin but they are also unesthetic and their use is limited to certain intraoral applications. Aramid fiber-reinforced denture base resin was found biocompatible, and additionally its flexural strength and flexural modulus were increased. However, the hardness of the resin decreased with increasing fiber concentration. Also, its yellow color is considered a drawback (Renu Tandon, 2010).

Polyethylene fiber reinforced: During the past few years, there has been a great deal of interest in the reinforcing effect of ultra high modulus polyethylene (UHMP) fibers on PMMA . The effect of unidirectional UHMP fiber reinforcement on the transverse strength of the Ph;IhlA depends on the amount of fibers present. Fiber contents a 5 high as 40 to 47 wt% considerably enhanced the transverse strength of' the composite (Vallittu, 2007). Multifibered polyethylene strands cut to 65 mm length and surface treated with epoxy-resin (to improve adhesion) are placed in resin during packing. They develop anisotropic properties to the composite (i.e. increase strength and stiffness in one direction).

Advantages: Exhibit highest impact strength and modulus of elasticity but flexural properties show no significant increase (Segerstrom, 2007).

Hypoallergenic Resins: Diurethane dimethacrylate, Polyurethane, Polyethylenterephthalate and Polybutylenterephthalate. Hypoallergenic denture base materials exhibit significantly lower residual monomer content than PMMA8, thus act as alternatives to Poly Methyl Methacrylate in allergic patients. Enterephthalate based (Promysan, thermoplastic) show low water solubility than PMMA (Pfeiffer et al., 2004). Light activated indirect composite containing methane dimethacrylate (UDMA) is an alternative to PMMA for patients hypersensitive to PMMA. But unfortunately these materials are not completely risk free (Tanoue, 2005).

Resins with modified chemical structure: Addition of hydroxy-apatite fillers increases fracture toughness (Mohamed, 2004). Addition of Al2O3 fillers increases the flexural strength and thermal diffusivity that could lead to more patient satisfaction (Ellakwa, 2008). The ratio of 2.2:1 by weight of powder to liquid was found to be the best ratio for mixing the material to give the best results in formulation (Mohamed *et al.,* 2004). 2% quaternary ammonium compound polymerised with a denture acrylic resin displays antiseptic properties and these dentures may be used for geriatric patients to improve their oral health. Addition of ceramic or sapphire whiskers to improve thermal diffusivity (Pesci bardon, 2006). Addition of 11-14% of several compounds of either bismuth or uranium or 35% of an organo-zirconium compound impart radiopacity equivalent to that of aluminium (Rawls, 1990). Addition of Triphenyl Bismuth (Ph3Bi) is a promising new additive to provide radiopacity. Rawls HR et al found that cytotoxicity of PMMA was elevated slightly by inclusion of Ph3Bi, probably due to decreased monomer conversion. But when stored in water, cytotoxicity was reduced, so there is high level of safety for Ph3Bi was a radiopaque additive for denture resins (Dixon, 1992).

Highly drawn linear polyethylene fibers (hdlpf): Patterns of continuous parallel fibers provide maximum reinforcement to both maxillary and mandibular bases. Reinforcement in maxilla is done by horizontally positioned fibers in anterior part of labial flange because maxillary fracture mostly occurs in midline on polished surface of palatal aspect in region immediately behind central incisors, which may be reduced by reinforcing the palate in lateral direction. Reinforcement done with 4 layers of fibers (2 in lateral direction sandwitched between 2 layers at 45 degree from middle ones.) by pre-preg technique (fiber content is 26% by volume). In mandible, maximum stresses appear in labial and lingual second premolar region and fracture occurs in middle region. Thus mandibular bases are reinforced with fibers at right angle to ridge located close to polished and fitting surface (these are regions where maximum strain occurs if flange movement takes place.). Between the two outer layers lies the main component of reinforcement i.e fibers in horizontal plane along dental arch.[20]

Advantages: HDLPF Have high tensile stiffness and strength, notch insensitivity and cracks do not propagate through array of fibers. The coherence is maintained even after a large number of testing cycles.

Thermoplastic Resins: This new procedure, during which a fully polymerized basic material is softened by heat (without chemical changes) and injected afterwards, has opened up a new chapter in making dentures.

Advantages of thermoplastic materials: Thermoplastic resins have many advantages over the conventional powder-liquid systems. They provide excellent esthetics with tooth or tissue colored materials and are very comfortable for the patient. These are very stable, resist thermal polymer unzipping, have high fatigue endurance, high creep resistance, excellent wear characteristics and solvent resistance. They are non-porous so no growth of bacteria, and even if it is non-porous, it still retains a slight amount of moisture to keep it comfortable against gums. They are unbreakable, flexible and light weight. Thermoplastic resins are a safe alternative to conventional resins because of very little or no monomer content. They may also be relined and repaired by repressing the restoration. These include thermoplastic Nylon (polyamide), thermoplastic acetal, thermoplastic acrylic and thermoplastic polycarbonate (Dixon et al., 1992).

Thermoplastic nylon: The Basic material of thermoplastic nylon is polyamide (derived from diamine and dibasic acid monomers). Thermoplastic nylon was introduced to dentistry in 1950's. It uses Rapid Injection System (currently known as The Flexite Company - USA) originated in 1962 which introduced the first flexite thermoplastic (a fluoropolymer - a Teflon type plastic). Thermoplastic nylon is injected at temperatures from 274 to 293 degrees Celsius. The application of nylon-like materials to the fabrication of dental appliances has been seen as an advance in dental materials. This material generally replaces the metal, and the pink acrylic denture material used to build the framework for standard removable partial dentures. Valplast and flexiplast are polyamides (nylon plastics), since then there is a continued interest in thermoplastic dental materials (Phoenix et al., 2004). In 1992, The Flexite Company, developed and patented the first pre-formed tooth colored clasps known as Clasp-Eze, made of nylon material and is available in pink and clear shades.

Advantages: It is virtually invisible (translucent allowing natural tissue to show through matching the basic shade categories – light pink, standard pink and meharry), and there are no metal clasps, only tissue coloured clasps that blend with natural teeth, thus provides excellent esthetics. Nylon is unbreakable, light weight and does not warp or become brittle. Because of its flexibility and incredible patient comfort nylon is ideal for patients considering a removable partial denture, and for those allergic to monomer. In addition, it involves non-invasive procedures and can be relined or repaired. Nylon shows no discoloration over time (colour fast) and is non-porous so no growth of bacteria, and even if it is non-porous, it still retains a slight amount of moisture to keep it comfortable against gums (Parvizi, 2004; Grumezescu, 2016; Luisa, 2012; Hoshika, 2011).

Limitations: Nylon is little more difficult to adjust and polish. Also it is not strong enough for conventional tooth borne rest seats.

Applications of thermoplastic resins: Current dental applications of thermoplastic materials include: preformed partial denture clasp, flexible tooth born partial denture framework, single cast partial dentures, temporary crowns and bridges, provisional crowns and bridges, occlusal appliances, implant abutments, orthodontic and sleep apnea appliances.

Enigma gum toning

- Custom shade matching of natural gingival tissue using 'Enigma' colour tones.
- Gives extra confidence to patient in appearance of their dentures.

- Available in Ivory, Light Pink, Natural Pink, Dark Pink and Light Brown. Different colors are mixed to get the desired gum tone.

Nanoscaled reinforcement materials: The concept of nanotechnology was first introduced in 1959 by Feynman. Since then, nanotechnology has been widely used in many applications, including medical sciences, and plays an important role in diagnosis, treatment, and regenerative medicine [27]. A nanomaterial is an object, which atleast one of its dimensions is at the nanometer scale (approximately 1 to 100 nm). Nanomaterials are categorized according to dimension – those with all 3 dimensions less than 100 nm [nanoparticles (Nps and quantum dots]; those that have 2 dimensionsless than 100 nm (nanotubes, nanofibers, and nanowires); and those that have one dimension less than 100 nm (thin films, layers, and coatings) (Chatterjee, 2010). The development of nanodentistry has led to nearly perfect oral health by the use of nanomaterials and biotechnologies, including nanorobots and tissue engineering. New opportunities in the fieldof dentistry include local anesthesia, treatment of dentin hypersensitivity, use of nanomaterials in preventive dentistry, and use of different nanofillers and nanofibers in composites to achieve better esthetics and mechanical properties (Elsaka, 2011). Here, we focus on new applications of nanomaterials for reinforcement of PMMA dental base materials.

Nanofillers: Recently, researchers have proposed the incorporation of nanofillers for reinforcement of denture base resins. Size, shape, surface area, concentration, and dispersion of nanofillers into resin matrix all affect the mechanical properties of the filler/resin composite. Alumina NPs, zirconia (ZrO_2) NPs, titania (TiO_2) NPs, silver NPs, gold NPs, Pt NPs, HA NPs, SiO_2 NPs, and nanoclay particles are among the fillers that have been introduced to enhance the mechanical properties of denture base acrylics (Bavykin, 2010). Silver Nps have been considered due to their distinctive physical, chemical, and biological properties, including high electrical and thermal conductivity, chemical stability, and non-linear optical behavior. It has been reported that silver Nps exhibit broad-spectrum bactericidal and fungicidal activities at very low concentrations (Cadek, 2002). Modification of polymers with nanoscaled TiO_2 have also been of interest with researchers because of its unique properties. Pleasing color, high biocompatibility, excellent mechanical properties, low cost, high stability, and appropriate antimicrobial effects are among the desirable properties which make TiO_2 a favorable additive for biomaterials (Wang, 2014). TiO_2 Nps have been used as an additive to improve both mechanical and antibacterial properties of different dental materials. Different attempts have made to add ZrO_2 Nps to PMMA denture base material to improve the mechanical properties.

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