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Eco-friendly and Biocompatible Acrylic Resins - A Review

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Abstract

A significant problem concerning the scientific application of acrylic based resins is their biodegradation. Changes of their chemical, physical and mechanical properties due to the oral environment circumstances can be well thought-out a definition of biodegradation. A chief clinically important significance of acrylic based resins biodegradation is the producing of leachable, potentially toxic agents, most frequently residual monomer, which in turn may induce a series of biological responses on cells and tissues. Further well-controlled clinical studies are necessary to improve the knowledge of materials biocompatibility in intraoral conditions.

Keywords: Biocompatibility, Dental Polymers, Polymethyl Methacrylate, Acrylic resins

Introduction

Acrylic-based resins are commonly used in every day dental exercise, as they are able to provide the necessary properties and have necessary characteristics for their use in diverse functions. Polymethyl methacrylate (PMMA)-based acrylic resins are used for fabrication of various dental prostheses and denture liners, temporary crowns and orthodontic appliances. Acrylic resin bases of removable partial or complete dentures and tooth-supported or implant retained over dentures are used to replace the lost tissues and transfer masticatory forces from the denture to the residual ridges. Acrylic based resins are frequently used in daily dental practice, as they are able to provide the essential properties and necessary characteristics to be used in diverse functions. Most common use of the materials includes denture bases and denture liners, orthodontic appliances and temporary crowns [1-3].

Denture bases are poised of pre-polymerized polymethylmethacrylate (PMMA) or polyethyl methacrylate (PEMA) powder particles along with a peroxide initiator and a pigment, which are mixed with methacrylate monomers (methyl-methacrylate, hexamethyleneglycoldimethacrylate, hydroxylethylmethacrylate, *n*-butylmethacrylate, tetrahydrofurfurylmethacrylate) and cross-linking agents such as ethylene-glycoldimethacrylate, tri-methylolpropane tri-methacrylate or 1,6-hexanediol dimethacrylate [4-6]. In the oral cavity, properties and functional values of acrylic resin based products depend on its endogenous factors caused by polymerization (degree of conversion of their constituent monomers, methods and the conditions of polymerization) as well as exogenous factors caused by conditions present in oral cavity (saliva, bacteria, mastication) [7]. All these factors make a complex and intricate interplay of interactions, resulting in significant biological effect on oral cavity tissues. Biological, as the most common toxic effect on oral cells and tissues, achieves a residual monomer that occurs as a result of the polymerization process and/or biodegradation of dental materials in the oral cavity. The aim of the review article to provide an overview of the current literature on toxicology of dental polymers and to give implications for possible improvements concerning their biocompatibility.

Biocompatibility

Biocompatibility can be defined as the properties of materials being biologically compatible without causing local or systemic responses of a living system or tissue. According to regulatory rules, biocompatibility is a number of tests for determining the possible toxic effects resulting from contact of the components of medical devices with the body. Another definition refers biocompatibility as the ability of a polymer material or a device to remain biologically inert during its functional period [8].

Biocompatibility of specific dental polymers

In scientific use of dental polymers, sensitive to reactions and chemical irritations

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have frequently been reported [8-12]. Hence, in patients with oral lesions we must keep in mind the incompatibility of dental materials. In addition, dental professionals should be aware of this issue. Largest part of dental restorative materials are composed of various methacrylate monomers, such as BisGMA and UDMA in combination with comonomers of lower viscosity, such as TEGDMA, EGDMA or diethylene glycol dimethacrylate (DEGDMA) [2-46-47]. Denture base polymers induced undesirable reactions have been attributed to substances leaching from these materials [13], particularly unreacted residual monomers [14]. When the water permeates into matrix, the leachable unreacted monomers diffuse out. Later on, they may be increased in the saliva and cause adverse reactions on oral mucosa.

The characteristic of released substances from the materials stated above has been evaluated by elution tests, such as Ultraviolet (UV) and Infrared (IR) Radiation, High Performance Liquid Chromatography (HPLC) and Gas Chromatography/Mass Spectrometry (GC/MS) [15]. It has been revealed that resin-based dental materials are tended to release so many compounds into aqueous or organic solvents. The studies mentioned above maintain that the contents of composite or adhesive resin are capable of being leached from the set material usually extraction is more extensive in organic solvents or alcohol according to water. Nonetheless, a few components are also leached into an aqueous media. Especially, substantial amounts of TEGDMA and HEMA may be released by polymerized composite resins into water. Bis-GMA, UDMA, TEGDMA, EGDMA, DEGDMA, 1, 6-hexanediol di-methacrylate, MMA, camphoroquinone, 4-N, N-dimethylaminobenzoic acid, ethyl ester, and varied other substances have been also defined in minor concentrations in aqueous extracts [16]. These monomers can modify cellular metabolism at subtoxic concentrations. The modifications may be accountable for clinical and subclinical effects [17].

It should be accepted that some unreacted methacrylate groups in resin-based materials are not capable of being leached into aqueous media due to their covalently bounds to one end of polymer chain. Hydrophilic monomers, such as TEGDMA were identified in higher proportions in aqueous extraction media than BisGMA [17]. Furthermore the hydrophilic monomers HEMA and TEGDMA were the only ones to be able to diffuse through the dentin into the pulp space at high concentrations in the mill molar range. Such concentrations may be high enough to cause harmful effects to the pulpal homeostasis and repair [18]. Additionally, the elution process from light -curing polymer-based materials is mostly proportioned to the amount of energy during irradiation. In addition, various studies indicate that cytotoxicity of composite resins is dependent to the mode of polymerization processes. These are curing unit, total energy density, power density, irradiation time and mode of curing (continuous or different modes) [19]. Bis-GMA is the most toxic dental monomer and the underlying cytotoxic mechanism is modification of the lipid layer of the cell membrane which changes membrane permeability [20]. In addition, water-soluble methacrylic acid produced by the hydrolysis of bis-GMA, can lead to cytotoxicity by increasing the release of tumour necrosis factor alpha [21]. An amphoteric monomer HEMA can displace water in dentin and can easily diffuse through the dentin [22]. It can also be mixed with most of the monomers used in composites. Hence, adhesive system components acting synergistically with HEMA could increase cytotoxicity which needs to be investigated. As a result of other relatively hydrophobic resinous composites are soluble in HEMA they might be carried through the dentin. HEMA is an effective mediator of apoptotic cell death at concentrations in a mill molar to micro molar range. After released at low amounts for an extended period of time, HEMA could decrease cellular proliferation and lead to apoptosis, likely via DNA damage [23].

The proportion of monomer–polymer conversion represents the number of unsaturated double bonds converting to saturated single bonds during polymerization. Residual monomer means to additives and reaction products are not tightly incorporated in the polymer network and may so leach. Afterwards, they may cause local or systemic toxicities, microbial side effects, oral mucosa and gingiva irritations, allergic reactions, mutagenicity and carcinogenicity. Recently, Nakagawa, et al. has shown that 4-Acryloyloxyethyl trimellitate anhydride/methyl methacrylate-tri-nbutylborane (4-META/MMA-TBB) is more biocompatible than other luting materials, because of its nontoxic polymerization properties [24]. In brief, the chemical and biological effects of 4-META/MMA-TBB resin were assessed for its potential use in dentistry. Firstly, 4-META/MMA-TBB resin underwent fast and highly rated polymerization with lower free radical production than PMMA or MDPDMA resins. Secondly, production of free radicals from 4-META/MMA-TBB was as low as from glass ionomer cement. Thirdly, the percentage of viable dental pulp cells was quite higher on MDPDMA and 4-META/MMA-TBB resin than on glass ionomer cement. Fourthly, META/MMA-TBB resin added to its uniquely convenient biochemical property during polymerization [24].

Biocompatibility of Dental polymers: Vascular performance

Because the oral cavity is highly vascularised, our knowledge about the effects of the dental polymers, which contain various diluent monomers that can interfere with vascular function, can be relevant to dental clinical practice. Therefore, dentists have studied vasoactive properties of dental polymers by examining their effects on vascular diameter of pulpal vessels by means of vital microscopy and Laser Doppler Flowmetry. Pharmacologists have joined the study by evaluating the effect of dental polymers on endothelium and smooth muscle of isolated rat aorta, which provided a practical, accurate, and reproducible study model. Using these methods, recent studies have shown that the newly developed dentin bonding agents and pulp capping materials contain various diluent monomers that can interfere with vascular function by causing vasodilation [25]. Moreover, commonly-used adhesive resin ingredients HEMA and TEGDMA may induce vasodilation [26]. Because a majority of proprietary dentin bonding agents incorporate HEMA and/or TEGDMA, their placement on iatrogenic pulp exposures might be responsible for the induction or reestablishment of pulpal haemorrhage. These effects may play a role in tissue homeostasis and certain adverse conditions associated with the use of dental resin materials. Since adequate microcirculation and oxygenation are the basic requirements for tissue survival, alterations in microcirculation may be an early sign of pathological changes. Vasodilation might impair pulpal healing by promoting haemorrhage in iatrogenic pulp micro exposures. Moreover, besides the presumed localized effects of the resin components on the oral microvasculature, there is the possibility that these compounds also can be released

from dental appliances and reach the systemic circulation to produce effects on other blood vessels. Accumulating evidence suggests that the key mechanism behind the vasodilatory action of dental polymers is through calcium antagonistic action [27]. Furthermore, it should be noted that several studies have shown that clinically relevant concentrations of these materials induce vasodilation in endothelium-denuded vessels, suggesting that the vasodilatory action is independent of the endothelium. Only a few studies suggest the presence of endothelium dependent and NO-mediated vasodilatation. Taken as a whole, numerous experimental studies provided evidence for the marked vasodilating effect of resin components. However, results from these in vitro studies need to be carefully extrapolated to the clinical situations, where the condition of the pulpal and apical vasculature is more complicated. Provided that these initial results are confirmed by clinical experimentation, more data will be available on future therapeutic opportunities for the dental pulp against the biological risks induced by such adhesive resins. In this regard, further studies especially with each of the various components available, are essential to understand the exact mechanism of the vasodilatory effect of dental polymers and to fully realize their implications in clinical dental practice.

Conclusion

Acrylic based resins are widely used in dentistry practice as restorative, liners or as denture base materials. These substances are made by polymerization of methacrylate related monomers. The numeral and diversity of processes by which acrylic based resins may be degraded in the oral cavity are huge and are now recognized as a complex interplay of interactions. Causes for biodegradation comprise several factors such as saliva characteristics, chewing or thermal and chemical dietary changes. There is opportunity for future research in different areas related to the evaluation of acrylic based resins biodegradation. This will lead to a more concise definition of biocompatibility issues related to these dental materials. The information acquired from such studies can also provide investigators with alternative polymeric chemistries that can be used in a new generation of materials able to induce favourable reactions in the living tissues.

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