

REVIEW ARTICLE

INJECTION MOLDING TECHNIQUE AND GENOTOXICITY IN DENTAL PRACTICE - A LITERATURE REVIEW

ABSTRACT

Biocompatibility of dental materials is of great concern for dentists, patients, public health services, competent authorities, standardizer's, dental technicians, laboratories, manufacturers and notified bodies. Several molding techniques have been advocated for processing denture base resins. Injection molding technique stand ahead as it has been proven to cause less dimensional change, less leachable methyl methacrylate and less exposure to laboratory technicians.

Key words: Injection molding, Genotoxicity, Poly methyl methacrylate

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INTRODUCTION

Researches concerning the biocompatibility of dental materials still remains contradictory.¹ Dentures, are prosthetic alternatives, constructed to replace missing teeth and are supported by the surrounding soft and hard tissues of the oral cavity. Dentures contribute towards improving mastication, aesthetics, phonation, and self-esteem in patients. Modern dentures are most often fabricated in a commercial dental laboratory or by a Prosthodontist using a combination of tissue shaded powders - Polymethyl methacrylate acrylic resin (PMMA) that are available as heat cured or chemically cured types. Polymethyl methacrylate (PMMA) offers numerous advantages of being highly aesthetic in nature and at the same time being cost-effective.²

In certain instances, patients show allergic reactions on the supporting mucosa after wearing PMMA prosthesis. The residual monomer in the prosthesis is thought to be the cause of the allergic reaction.³ Oral reactions to acrylic resins include symptoms such as burning mouth and tongue, redness, and erosions of the oral mucosa. Causes of these symptoms include trauma from ill-fitting dentures, local chemical irritation caused by acrylic resin or its constituents, or other systemic and oral diseases not related to acrylic resin. Ill-fitting or poorly adjusted dentures are the most common cause of denture discomfort. Methyl methacrylate monomer has also been shown to be a primary irritant, eliciting a localized inflammatory response by direct action on the tissues. Allergic reactions to methyl methacrylate monomer are usually observed as contact dermatitis. Completely polymerized methyl methacrylate probably does not cause such reactions.⁴

Physico-chemical features of denture base resins

A polymer is a high molecular weight chemical compound, which by means of a repeated intermolecular chemical reaction becomes a long-chain and/or cross-linked macromolecule composed of several repetitive united molecules with a lower molecular weight (monomers).^{5,6,7} In the dental field most of them are organic molecules, particularly derived

from methacrylates.⁶ Other types of polymers based on polyacrylic acid (PAA) or poly dimethyl siloxane (PDMS) are also widely employed in dental practice.⁸

Though dental polymers are considered insoluble in water, imbibition may occur, resulting in undesirable dimensional alterations. The water/solvent molecules are adsorbed through the porosities and inter-chain spaces and expand the matrix network (plastification).⁹ As a consequence, the polymer softens and swells, but does not dissolve, compromising the material's clinical performance.⁶

Polymerization may occur by two distinct processes: addition or condensation. The condensation (growth-step) reaction is typical of elastomers and is characterized by a simultaneous reaction of the bifunctional monomers that gradually connect each other and many times, as a consequence, may produce low molecular weight byproducts. Conversely, during the addition polymerization, which is the most usual in the dental field, the monomers are activated one by one, but are rapidly added to the main chain without changing the composition and, theoretically, can produce almost unlimited giant molecules if monomer is available.⁶ The addition polymerization reaction is exothermal, reaching considerably high temperatures. It has been reported that auto polymerizable PMMA acrylic bone cement's peak temperature may range from 50-120°C.⁹

The reaction may be inhibited or delayed by the presence of impurities and the contact with oxygen, which react with the free radical sites of either the activator agent or a growing polymer chain. Hydroquinone (HQ) (<0.006%) may be added to the monomer composition as an inhibitory agent, avoiding its spontaneous polymerization.⁶

Residual monomer as a biological hazard

Stomatitis is a multifactorial oral condition that has been extensively associated with PMMA denture base resins, which may be caused or related to poor oral hygiene, mechanical trauma, wearing denture during the night, smoking, systemic and nutritional conditions, bacterial and fungal infections, as well

as reactions to chemical aggressions such as mucosal irritation or allergy by MMA.¹⁰⁻¹³ Prevalence has been reported to be between 15 and 70% in denture wearers, and it is more frequent in elderly people and women.¹²

Patients have registered diverse systemic reactions to dental acrylic resin such as contact dermatitis and asthma, local inflammatory lesions like lichen planus, gingivitis, ulcerations, eczema, erythema, blisters and erosions, papilloma, fibroma, and burning mouth sensation, especially on the mucosal surface of the prosthetic support and oral adjacent tissues.^{14,15,16} Acrylic resin contact allergy in patients is a rare condition, since the polymerized PMMA is non-sensitizing.¹⁷ Polymers being macromolecules, risk of gastrointestinal or dermal absorption is minimal and the respiratory tract contact is considered negligible.¹⁸ Studies have however shown that unpolymerized acrylic monomers generally induces sensitization and/or irritation and is widely recognized in professionals related to dentistry (dentists, dental assistants and technicians and methacrylate manufacturing personnel) in form of allergic contact dermatitis in hands or face, occupational respiratory hypersensitivity and local neurological injuries.^{17,19,20} Use of clinical gloves has shown to provide only a limited protection from MMA contact.¹⁹

The relationship between increased prevalence of death caused by respiratory, stomach or colo-rectal cancers and occupational exposure to MMA in the manufacture of PMMA products and concluded that the cancer cases were probably more related to life style habits. Hence there is little evidence that MMA is a human carcinogen.^{21,22}

Generally, heat-polymerized acrylic resins are mostly preferred in dentistry. Despite its satisfactory properties, it has the potential to elicit irradiation, inflammation and allergic reactions in the oral environment. Acrylic resins contain methyl methacrylate monomer, methacrylic acid, benzoic acid, plasticizers, phenyl benzoate, phenyl salicylate and dicyclohexyl phthalate. These materials can be responsible for hypersensitivity and allergic conditions to dental laboratory persons and denture wearers prior to and after the polymerization.²³

Acrylic resins have been modified to improve physical and chemical properties through processing techniques such as injection molding. There are many injectable PMMA systems and they claim to fabricate more accurate denture bases than conventional PMMA by constant flow of material from the sprue compensating for the polymerization shrinkage.^{24,25} The processing technique, rather than the choice of the resins, seems to be the dominant variable with respect to dimensional changes.²⁶

The trapped residual monomer may leach from the polymer in clinical conditions and consequently can cause biological hazards, such as cytotoxicity and genotoxicity.²⁷ The smaller molecular monomers are more cytotoxic and there is a direct linear relationship between cytotoxicity and molecular hydrophobicity. The hydrophobic molecules can interact with the phospholipid bilayer of the biologic membranes.^{28,29}

Auto polymerized acrylic resin shows a higher level of residual monomer than heat-cured resin.³⁰ Higher amounts of methylmethacrylate (MMA) was detected in the saliva of subjects wearing dentures made from auto polymerized resins compared with heat-cured resins.³¹

These resins performed higher cytotoxic effect than heat-polymerized resin and it was statistically significant at 1-day period and that the highest cytotoxic effect was observed at 5-day incubation period.³²

Microwave post-polymerization irradiation can be an effective method for increasing the flexural strength of denture liner (at 650 W for 5 minutes) by reducing the residual monomer content by further polymerization at free radical sites.³³ Residual monomer content in acrylic dentures could be detected for up to several years after use. While it appeared that most of the residual monomer was lost after about five years, complete loss of the residual monomer content may take many more years.³⁴

Injection molding technique

Among denture processing methods, injection molding has always been interesting for researchers

because of compensation of polymerization shrinkage due to the pressure exerted by injection of the acrylic resin.³⁵

Smaller resin particles, lower polymerization temperature, absence of resin film formation between the two halves of the flask, and absence of displacement of the two halves of the flask during resin packing, may be the causes for better dimensional accuracy of the injection molding technique.³⁶ Injection-molded acrylic resin generally requires a greater monomer content to improve flow characteristics and facilitate filling of the mold cavity, often resulting in additional unreacted monomer within a polymerized acrylic resin.³⁷ The cytotoxicity may be reduced by controlling the acrylic resin monomer/polymer content by manufacturer in capsule form and thus decreasing the unreacted residual MMA original ready to use ratio. In case of compression molded technique as the monomer polymer ratio is carried out by dental auxiliary staff, it is not always accurately possible for complying with the manufacturer's instructions.³⁸ From a health and safety perspective, the injection process eliminates the direct handling of resin during the packing process that significantly reduces methyl methacrylate exposure. From a laboratory perspective, the technique could be completed in a relatively short period and does not require repetitive opening and closing of the flask. Also, this process minimizes the likelihood of underpacking or overpacking the mold cavity.³⁹

Chopped E-glass fibers shows an increase in transverse strength, elastic modulus and impact strength of injection-molded denture base polymer.⁴⁰ Injection molding procedure exhibits less shrinkage than those produced by the conventional press-pack procedures.⁴¹ Injection molding have demonstrated a slightly less increase of vertical dimension of occlusion than conventional polymerization techniques.^{42,43,44} This molding technique have been shown to have a less dimensional change than those cured by the conventional and the microwave curing methods producing a more accurate denture base.⁴⁵ Injection-molded resin shows better internal adaptation compared with the conventional heat-polymerized and the microwave-

polymerized resins, particularly after 30 days.⁴⁶

DISCUSSION

Retention rates for natural teeth are on the rise, indicating a significant reduction in the demand for removable prosthesis.^{47,48} Middle-aged populations experience improved health care and longer life spans compared to previous generations. There is a possibility that edentulism could rapidly decline. More current information, however, supports the fact that the number of older adults is on the rise and that the number of edentulous elderly will actually increase in the next two decades.^{49,50}

Acrylic resins, which are the most commonly used material for dentures, are usually composed of prepolymerized polymethyl methacrylate (PMMA) powder particles, which are mixed with monomers of methyl methacrylate (MMA).⁵¹ Despite various methods being employed, such as chemical activation, visible light activation, or heat activation using hot water or microwave energy, to initiate the polymerization of denture base resins, the conversion of monomer to polymer is never complete and some unreacted monomer, called residual MMA monomer, is left in the denture base polymer.⁵²

This residual MMA is considered an allergen⁵³ and can cause local adverse reactions, such as erythema, burning sensation, edema, fissures, necrosis, pain.^{54,55} It has also been shown to cause systemic reactions,⁵⁶ such as - labial edema,⁵⁴ chronic urticaria,⁵⁷ difficulty in swallowing, and hypersalivation.⁵⁸ Studies documents the allergic tendencies towards MMA resins in a 60 year old lady despite the residual content of monomer being within the international standards. Also a patch test on the patient revealed positive reactions.⁵⁹ MMA is also considered cytotoxic⁶⁰ as well as possibly genotoxic.⁶¹

Various in vitro studies also showed the leaching of monomer at a higher value during the first week. Residual MMA released into saliva after incubation for 24 hours can cause cell toxicity in vitro and wearing of newly made dentures could cause oral tissue irritation because of these leachable substances. Monomer could also leach out of the denture base

when immersed in water.⁶² Minor irregularities of fit in new dentures may also result in irritation that makes the mucosa more susceptible to MMA in the first few days. Hence it is of necessity to advise the patient to immerse the denture in water at room temperature during night or when not in use.⁶³

Various studies have shown that the residual monomer is highest during 24 hours after insertion, and then decreases further. The leaching of residual monomer even though in low quantities, can sustain for many years.⁶⁴

Literature shows that the techniques used for molding denture base resins could also be a factor in determining the amount of residual monomer content. Irrespective of the denture base resin used, genotoxicity was more prominently seen with compression molded technique, when compared to injection molding technique. Main cause attributing genotoxicity is the amount of monomer which is in turn altered with altering the Powder - Liquid ratio.⁶² In case of injection molding pre weighed cartridges are used which helps in reducing the residual monomer content. This is not completely possible by manual mixing in case of compression molding. Also, the additional pressure used in injection molding can reduce the residual monomer content.

CONCLUSION

Selecting a suitable denture base material and processing with injection molding technique will aid in limiting the extent of genotoxicity and could reduce the potential side effects to the patient considerably. It will also aid in fabricating removable prostheses with minimal genotoxicity and limit other concerns in patients. A poly methyl methacrylate denture base material that is less genotoxic will offer patients, complete dentures with minimal side effects and adequate biocompatibility. It is recommended that the patients be advised not to wear newly made dentures overnight, as this may cause mucosal irritation from the potential effects of leachable substances.

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