Cytotoxicity of denture base acrylic resins: A literature review

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Acrylic resins are widely used in the fabrication of denture bases and have been shown to be cytotoxic as a result of substances that leach from the resin. The primary eluate is residual monomer. Numerous reports suggest that residual monomer may be responsible for mucosal irritation and sensitization of tissues. This information is important, not only to assess the biologic effects of such materials, but also to enable a comparison among the different polymerization methods, thus assisting the clinician in selecting a material with minimal cytotoxicity. This article reviews the literature published from 1973 to 2000, selected by use of a Medline search, associated with cytotoxic effects usually ascribed to acrylic denture base materials. (J Prosthet Dent 2003;90:190-3.)

Residual monomer, resulting from incomplete conversion of monomers into polymer, has the potential to cause irritation, inflammation, and an allergic response of the oral mucosa. Clinical signs and symptoms most frequently reported include erythema, erosion of oral mucosa, and a burning sensation on the mucosa and tongue.[1]

The effects of toxic substances leached from the resins on tissues have been reported by clinical observations,[2-5] in animal models,[6,7] and by in vitro cell growth.[8-21] Testing of dental materials by cell culture methods are relatively simple to perform, reproducible, and cost-effective, and they can be carefully controlled. These tests may be more suitable as an alternative to the costly, controversial animal experiments, which may also have several uncontrollable variables.

Resins used for the manufacture of denture bases have displayed various degrees of in vitro cytotoxicity and in vivo allergic responses, probably caused by unreacted components remaining after the polymerization process. Residual monomer concentration varies with the methods and the conditions of polymerization.[1,22,23] The variations in chemical composition and purity of the commercially available resin systems, the degree of conversion of their constituent monomers, and manipulative variables may all affect the biologic and physical properties of the acrylic resins.[16] Nevertheless, acrylic resins are still widely used for the fabrication, reline, and repair of prostheses even though no biologic testing is required for their use in dental practice because they are considered to be low-risk materials for patients' health.[24] This article reviews the literature published from 1973 to 2000, selected by use of a Medline search (US National Library of Medicine), on the cytotoxicity of acrylic denture base materials comparing different types of resins and the different polymerization methods and cycles.

EFFECT OF POLYMER TO MONOMER RATIO

The polymer to monomer ratio is one of the variables that influences the cytotoxicity of denture base acrylic resins. According to Kedjarune et al,[23] the more monomer added to the mixture, the greater the amount of residual monomer and, therefore, the more potential for cytotoxicity. Similarly, Lamb et al[25] investigated the effect of polymer to monomer ratio on residual monomer levels and observed that resins prepared with a high proportion of polymer (5:3) resulted in significantly lower levels of residual monomer, as compared to those prepared with a lower ratio (4:3). However, it is important to note that different polymer to monomer ratios can result in an acrylic resin mixture that could be either too stiff or too fluid for clinical use.

EFFECT OF STORAGE TIME AND WATER IMMERSION

Storage time is another feature that plays an important role in the cytotoxicity of acrylic denture base materials. Sheridan et al[18] reported that the cytotoxic effect of acrylic resins was greater in the first 24 hours after polymerization and decreased with time for all the resins evaluated in their study. The authors concluded that the longer a prosthesis is soaked, the less cytotoxic effect it is likely to have regardless of the denture base resin it is manufactured from. Lefebvre et al[16] observed the effects of substances released from 4 light-polymerizing denture base resins on hamster oral epithelial cells. Their findings indicated that components released by light- or heat-polymerized acrylic resins may produce toxic effects on oral epithelial cells, leading to greater cellular inhibition in the initial 24-hour period on the basis of cell numbers.

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In addition, different substances can be released in different concentrations changing the physical and chemical properties of the materials.[16] The cytotoxic effect may occur for several days after polymerization, but it can be minimized if the prostheses are stored in water for 24 hours.[16,18] It is hypothesized that the toxic substances released into the medium within the first 24 hours are either broken down over time or complexed with other chemicals in the medium that may alter their cytotoxic potential.[18] Therefore, it is recommended that dentists soak the acrylic resin prostheses in water for at least 24 hours before placing them in the patient's mouth. It has been advocated that the prosthesis should be immersed in water at 50°C for 60 minutes, to reduce the amount of released monomer and therefore the toxic potential of denture base resins, especially for autopolymerized resins. This is particularly important when hard autopolymerized reline resins are used.[26] Weaver and Goebel[1] reported that the immersion of prostheses in heated water decreased the hypersensitivity reaction in the examined patients. According to the authors, the decrease in the amount of residual monomer after this procedure may be due to further polymerization in the presence of free radicals. By immersing the prosthesis in heated water, monomer molecules diffuse more rapidly, reaching the remaining free radicals and leading to a complementary polymerization reaction.

EFFECT OF POLYMERIZATION CYCLE

Depending on the polymerization temperature and time, various quantities of residual monomer are left in the polymer resulting in different degrees of cytotoxicity. Kedjarune et al[23] observed a reduced amount of residual monomer when the polymerization time was extended, thus resulting in less cytotoxic effects. To define an ideal polymerization cycle for different acrylic resins, Harrison and Huggett[27] conducted a study wherein 23 heat-polymerized denture base polymers were subjected to various polymerization cycles. The results of this investigation showed that a 7-hour incubation in water at 70°C followed by 1 hour at 100°C was ideal, because it provided maximum conversion of residual monomer. In contrast, a 7-hour cycle at 60°C and the cycle of immersing the flask in boiling water, followed by a 5-minute immersion in water at 90°C, produced a high concentration of released residual monomers. To assess the effect of temperature and polymerization time on the amount of residual methyl methacrylate monomer, Vallittu et al[28] performed a study with 2 autopolymerized resins in which the reaction was initiated by barbituric acid and 2 heat-polymerized resins activated by benzoyl peroxide. The results showed that autopolymerized resins exhibited higher contents of residual methyl methacrylate than the heat-polymerized resins. This may be due to the rise of temperature in heat-polymerized resins, which resulted in mobility of the molecular chains, thereby facilitating the conversion of monomer into polymer. Thus, heating cycles with temperatures less than 100°C may result in polymers with higher methyl methacrylate contents than heating cycles with temperatures in excess of 100°C. It was also demonstrated that for autopolymerized resins, in which only the polymerization temperature was varied, the amount of residual monomer decreased as the temperature increased. Moreover, Lamb et al[25] observed that levels of residual monomers in autopolymerized resins were higher for specimens polymerized at 22°C, as compared with those polymerized at 55°C. Therefore, it seems reasonable to suggest that the autopolymerized acrylic resins should be heat-treated to decrease cytotoxic effects.

EFFECT OF POLYMERIZATION METHOD

The method of polymerization is a decisive feature in the cytotoxicity of denture base acrylic resins. According to Hensten-Pettersen and Wictorin,[9] the cytotoxic effect is greater in autopolymerized resins than in heat-polymerized resins. The cytotoxic effects of heat-activated, chemically-activated, and microwave-activated acrylic resins on gingival fibroblasts were also reported by Sheridan et al,[18] who observed that, among the tested materials, the greatest cytotoxic effect was produced by the chemically activated acrylic resins. The findings of Tsuchiya et al[26] and Cimpam et al[20,21] revealed that autopolymerized resins eluted considerably more substances than did the heat- and microwave-polymerized resins. Yunus et al[29] studied the effect of microwave heating on the residual monomer level of an autopolymerized resin used in the repair of prostheses. The results demonstrated that the specimens submitted to microwave irradiation after 20-minutes of autopolymerization showed a reduced amount of residual monomer when compared with resins undergoing other polymerization methods. A similar finding was observed by Blagojevic & Murphy[30] who showed that the residual monomer of an autopolymerizing resin decreased by approximately 4-fold when specimens were submitted to microwave irradiation. Therefore, it may be assumed that the reduction in residual monomer content by microwave irradiation could play an important role in decreasing the cytotoxic effects of autopolymerizing acrylic resins due to the heating that occurs. De Clerk[31] also reported a lower amount of residual monomer after microwave processing when this method was compared with the conventional heat-polymerizing technique. Thus, a shorter polymerization time and less residual monomer are considered as 2 of the advantages of microwave polymerization. Truong and Thomasz[32] compared the residual monomer release of acrylic denture

base resins polymerized by hot water and microwave energy. Specimens polymerized by conventional methods exhibited slightly higher concentrations of residual monomer compared with specimens polymerized by microwave irradiation. The results from Al Dori et al[33] revealed that microwave irradiation yielded a substantial reduction of residual monomer and a high degree of conversion of denture base acrylic resins tested.

Visible light-polymerized denture base resins were introduced in the early 1980s. Although these resins have been reported to be nontoxic after polymerization,[34] several studies have shown that these materials have varying levels of cytotoxicity.[14,17] The extent of their toxic effect appears to be related to the specific formulation of the material[11] and polymerization time. Increasing the polymerization time may decrease resin toxicity.[14] Soaking prostheses fabricated with light-polymerized resins for 24 hours before insertion has been recommended to minimize exposure of oral tissue to cytotoxic substances[35] such as methyl methacrylate and bis-GMA.[11]

To summarize, the reviewed studies indicate that autopolymerized resins are more cytotoxic than the heat-polymerized denture base resins, which in turn are more cytotoxic than the microwave-polymerized resins.[18] One explanation for such performance could be that microwave irradiation produces high-frequency motion of monomer molecules, increasing internal heat and, consequently, resulting in greater conversion of monomers into polymer.[31] Therefore, less residual monomer amount is 1 of the advantages of microwave polymerization, which leads to a reduction of the toxic effects of acrylic resins.

Another important consideration is the impact the type of polymerization has on the physical properties of the denture base resins. The residual monomer concentration is the most important parameter in determining variations in mechanical properties of a denture base material.[27] Considering that the amount of residual monomer is dependent on the type of polymerization, it is likely that a cycle of 7 hours at 70°C and 1 hour at 100°C, which promoted lower amounts of residual monomer, would result in denture bases with less cytotoxic effects.

It is important to emphasize that the results of cytotoxicity tests present limitations with regard to their applicability to clinical situations. Findings from either these in vitro tests or those performed in vivo (secondary or application tests) cannot be extrapolated to the clinical setting. Nevertheless, such tests are important because they provide vital information with respect to the biologic behavior of dental materials and their components. Further studies are necessary to identify the individual toxic components of the denture base acrylic resins and to elucidate the mechanisms involved in the interactions between cells and denture base acrylic resins.

SUMMARY

Even though the results of initial cytotoxicity tests cannot be immediately extrapolated to clinical conditions, they may be important in defining the biologic behavior of dental materials and their components. Cytotoxicity testing allows a comparison among available products and information for choosing a material with an optimal polymerization method and cycle for denture base resins. On the basis of the review of literature, it may be concluded that the cytotoxic effect of denture base acrylic resins may be related to storage time, powder to liquid ratio, polymerization method, and cycle. Autopolymerized resins are the most cytotoxic denture base material. Acrylic resins polymerized by microwave irradiation are less cytotoxic, probably because of greater conversion of monomers into polymer. In addition, water storage may reduce the level of residual monomer, resulting in decreased cytotoxicity of these acrylic denture base materials.

The authors thank Dr Vehid Salih from the Eastman Dental Institute for Oral Health Care Science for reviewing the manuscript and for wise suggestions.

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0022-3913/2003/$30.00 + 0

doi:10.1016/S0022-3913(03)00349-4

Noteworthy Abstracts of the Current Literature

Complications after treatment with implant-supported fixed prostheses: A retrospective study
Catharina Göthberg, Tom Bergendal, and Tomas Magnusson.
Int J Prosthodont 2003;16:201-7.

Purpose. The aim was to retrospectively evaluate the frequencies of different complications, as well as the number of visits to dentists because of such complications, after treatment with implant-supported fixed prostheses.

Materials and Methods. The study group comprised 75 patients who had been treated with implant-supported fixed prostheses 3 years earlier. All case records were scrutinized, and notes of complications in association with implants and superstructures were registered.

Results. The most common intervention made was occlusal adjustment/selective grinding of the prostheses. Complications in association with both implants and superstructures were fairly common. The most frequent complication was fractures of the acrylic resin matrix, including artificial acrylic resin teeth. Consultations because of periimplant mucosal inflammation were much more common among women compared to men, while complications that could be attributed to heavy loading tended to be more common in men.

Conclusion. Complications with both implants and superstructures are fairly common after treatment with implant-supported fixed prostheses. Regular follow-ups to maintain optimal function in these patients are thus mandatory.—Reprinted with permission of Quintessence Publishing.