Acrylates

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ACRYLATES HAVE been around since the 1930s, when Rohm and Haas began mass production of Plexiglas, a clear and resistant glass substitute made of polymerized methacrylate.[1] It is used extensively for windowpanes, airplane canopies, car lights and windshields, streetlamps, and so on. Numerous other acrylates have been synthesized and have found applications in paints and adhesives, dental composite resins, printing inks, artificial nails, and medical devices such as contact lenses, hearing aids, and bone cement for orthopedic endoprostheses.

CHEMISTRY

The salts of acrylic or methacrylic acid can be polymerized to form solid plastics. Monofunctional (meth)acrylates will link together through their single vinyl group to form long, parallel strands that can be melted and become rigid when the temperature is lowered (thermoplastic resins). Multifunctional (meth)acrylates possess more than 1 vinyl group and are used to cross-link the polymer strands. The resulting thermosetting resins are much more rigid but cannot be melted and must be given their definite shape before hardening occurs. The addition of prepolymers, hybrid molecules such as epoxy or urethane acrylates, will make molding easier.

Polymerization, or curing, can occur at room temperature or with heat. This process requires the presence of initiators and accelerators.[2] Nowadays, numerous (meth)acrylates, mostly used in dental bonding materials, printing inks, and artificial nails, are polymerized by exposure to UV light with help from a priming photoinitiator. In certain systems, curing can be accomplished with ionizing radiation, in the absence of oxygen (anaerobic sealants), or by exposure to water moisture (cyanoacrylate instant glues).

IRRITANT AND ALLERGIC CONTACT DERMATITIS

Fully polymerized acrylic plastics are inert and harmless. The monomeric building blocks acrylates and, to a lesser extent, methacrylates are strong irritants,[3–5] but they are also notorious allergens. Since the 1950s, numerous case reports have documented allergic contact dermatitis. Methyl methacrylate (MMA) in sculptured artificial nails has caused severe periungual dermatitis, often accompanied by nail destruction and painful, persistent paresthesia.[6–10] The dermatitis is at times ectopic, transferred from the fingers to distant sites such as the trunk, the face, and eyelids.[11] For this reason, in 1974, the Food and Drug Administration banned the use of MMA in artificial nails. Unfortunately, the alternative acrylates introduced by the industry, including the new UV light-cured "gel" nails, happen to be as sensitizing as MMA.[12,13]

In the occupational setting, publications have described severe hand dermatitis with painful fissures and desquamation in orthopedic surgeons and nurses exposed to MMA monomer in bone cement.[14] Beauticians who apply artificial nails have also become sensitized to MMA and other (meth)acrylates,[15] with some being falsely led to believe that the products were free of acrylates. Dental surgeons, assistants, and technicians are also at risk of allergic sensitization from monofunctional and polyfunctional (meth)acrylates and from the epoxy acrylate prepolymers.[16] Similarly, printers working with UV-cured acrylates in making printing plates or involved in silk screen printing have become sensitized.[17,18] Machinists or mechanics using Loctite, Sta-Lok, or other anaerobic sealants to prevent loosening of screws and bolts have also developed allergic contact dermatitis.[19,20] Acrylate-based medical equipment has been responsible for contact allergy to hearing aids,[21] electrocardiogram conductive gel,[22] transcutaneous electrical nerve stimulators,[23] electrosurgical earthing plates,[24] and insulin infusion pumps.[25]

PROTECTION

(Meth)acrylate monomers can penetrate most gloves within minutes, especially vinyl and latex gloves.[26] The best protection is conferred by laminated polyethylene/ethylene vinyl alcohol, but these gloves are inelastic and expensive. Double gloving with nitrile gloves, or polyethylene gloves under nitrile gloves, affords adequate protection for tasks that do not exceed 30 to 60 minutes.[27]

PATCH TESTING

(Meth)acrylates are tricky molecules to test with. The concentration that will reveal allergic sensitization is close to the irritancy threshold. Furthermore, these molecules can induce active sensitization.[28] Methacrylates are tested at 2%, acrylates at 0.1%, and cyanoacrylates, once falsely thought to be nonsensitizing because

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TABLE 1. *Dermatitis* Contact Allergens of the Year

2011 (volume 22, number 1)	
Dimethyl fumarate	
Magnus Bruze	
Erik Zimerson	
2010 (volume 21, number 1)	
Neomycin	
Denis Sasseville	
2009 (volume 20, number 1)	
Mixed dialkyl thiourea	
Bryan E. Anderson	
2008 (volume 19, number 1)	
Nickel	
Rachel Komik	
Kathryn Zug	
2007 (volume 18, number 1)	
Fragrance	
Frances J. Storrs	
2006 (volume 17, number 2)	
***P*-Phenylenediamine**	
Vince DeLeo	
2005 (volume 16, number 1)	
Corticosteroids	
Marlene Isaksson	
Magnus Bruze	
2004 (volume 15, number 1)	
Cocamidopropyl betaine	
Joseph Fowler	
2003 (volume 14, number 1)	
Bacitracin	
Apra Sood	
James Taylor	
2002 (volume 13, number 1)	
Thimerosal	
Donald Belsito	
2001 (volume 12, number 1)	
Gold	
Joseph Fowler	
2000 (volume 11, number 1)	
Disperse blue dyes	
Frances Storrs	

of their rapid binding to surface keratin, are tested at 10%. Petrolatum is the preferred vehicle, because it slows down spontaneous polymerization, a phenomenon that can be worsened by aluminum test chambers.[29]

Some authors have suggested screening series of patch-test allergens.[30–33] None of these series will pick up every case, but most will be detected if tested with MMA, 2-hydroxymethyl methacrylate (2-HEMA), ethyl acrylate, ethylene glycol dimethacrylate (EGDMA), triethylene glycol diacrylate (TREGDA), and ethyl cyanoacrylate. Extended series will be necessary in most occupational cases, as well as testing with the patients' own products, appropriately diluted.

NEW DATA

Most patients in case reports of allergic contact dermatitis to (meth)acrylates have multiple sensitizations when patch tested. These have been regarded as cross reactions. However, chemical analyses carried out by investigators at the Finnish Institute of Occupational Health have shown that most acrylate-based industrial products contain numerous other acrylates as impurities, sometimes as much as 46% of the total weight of the product.[34] These additional compounds are not disclosed on material safety data sheets. Many of the so-called cross reactions could in fact be concomitant reactions. The same group verified the purity of commercially available patch-test allergens.[35] Although they found dimethacrylates to be very pure, diacrylates and triacrylates contained between 9% and 19% of the corresponding monoacrylates and hydroxyacrylates. These impurities in patch-testing materials may also be responsible for falsely positive cross reactions.

True cross reaction, however, occurs between ethyl acrylate and dimethyl fumarate, the infamous antifungal responsible for the Chinese sofa epidemic and allergen of the year 2011.[36] It is likely that fumaric acid isomers such as the maleates, used in polyvinyl acetate glues, could also exhibit cross reactions with acrylates.

(Meth)acrylates are volatile compounds, especially MMA. A Swedish group recently published a thought-provoking article about the concentration over time of 5 (meth)acrylates kept in syringes and loaded in IQ chambers (Chemotechnique Diagnostics, Vellinge, Sweden), stored at 23°, 4°, and 0° Celsius.[37] Syringes containing 2-HEMA, EGDMA, and TREGDA retained 80% of their initial concentration up to 128 days regardless of the storage temperature. Methyl methacrylate was below the 80% mark after 8 days if kept at room temperature, at after 10 days if refrigerated. The times to decrease below the 80% acceptable concentration for similarly stored 2-hydroxypropyl acrylate (2-HPA) syringes were 21 and 105 days. All allergens were rapidly lost when preloaded in IQ chambers, usually within a few hours (MMA and 2-HPA) or 2 days (2-HEMA and EGDMA). Triethylene glycol diacrylate is slightly more stable, reaching 80% of its initial concentration after 5 days if at 23° and 32 days when refrigerated.

CONCLUSIONS

Acrylates are everywhere, and their use is likely to increase. The monomers are strong irritants and allergens. The criterion standard to uncover allergic contact dermatitis to these finicky molecules is patch testing. After years of trial and error, the patch-testing concentrations for the various acrylates and methacrylates have been established, but active sensitization can still supervene with commercially available allergens, especially if extensive series are applied. It is recommended to test with as few allergens as possible when investigating suspected cases of allergic contact dermatitis.

The volatility of patch-test materials raises some concerns for the patch tester. (Meth)acrylate allergens should be kept frozen, or

at least refrigerated, in capped polyethylene syringes. They should be used before their expiry date, and they should be loaded in patch-testing plastic chambers immediately before application to patients' backs.

Despite the plethora of publications on (meth)acrylates over more than half a century, new information keeps surfacing about these fascinating chemicals, enough recently to justify their accession to the rank of "allergen of the year."

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