

Hand/Face/Neck Localized Pattern: Sticky Problems—Resins

Lauren Y. Cao, BS, MD/MS^a, Apra Sood, MD^b, James S. Taylor, MD^{b,*}

KEYWORDS

- Plastic • Resin • Epoxy • (Meth)acrylic
- Polyurethane • Phenol-formaldehyde
- Allergic contact dermatitis
- Irritant contact dermatitis

Plastics are a complex group of chemicals with continuously expanding uses in a wide range of industries. They are large polymers made from the combination of simple monomeric subunits. The production of plastics uses oil; 5% of the world's total oil production is applied to the synthesis of plastics.¹ Whereas plastics are synthetic polymeric end products, resins are low-, medium-, and high-molecular-weight (MW) intermediate synthetic compounds from which plastics are made.¹

Most dermatologic and other health hazards occur during the production and manipulation of plastics rather than during the use of the final product by the consumer.² Dermatoses from synthetic plastic resin systems are caused mostly by epoxies, with fewer reactions to other resins (**Box 1**) and their additives.² Final plastic products which are completely cured are generally harmless to the skin unless machined (eg, by sawing, sanding, drilling, buffing), whereas dermatoses do arise from plastic components of low MW, such as monomers from uncured or incompletely cured resins, hardeners, reactive diluents, degradation products, and other additives.^{1,2}

Contact dermatitis, irritant (ICD) or allergic (ACD), is the most frequent presentation after exposure to components of synthetic plastic resin

systems.² It usually first appears on the hands and fingers in small patches, and may easily spread to other body areas (eg, face, eyelids, neck) by indirect contact (eg, via the hands).² Some resins and additives may be volatile, which means that exposure to their vapors or dusts may cause airborne dermatitis on exposed body areas.²

EPOXY RESINS

Epoxy resins are commonly used chemicals of which 75% to 90% are based on diglycidyl ether of the bisphenol A (DGEBA), formed from a combination of epichlorohydrin and bisphenol A.^{1,3} When various proportions of epichlorohydrin and bisphenol A are used during manufacturing, different amounts of low- and high-MW epoxy resins are produced. Epoxy resin systems (ERSs) consist not only of uncured epoxy monomers but also additives and modifiers (**Box 2**). Carbon and glass fibers are sometimes impregnated with ERSs to increase the strength of materials in products such as those required in aircraft manufacturing.^{1,4,5} However, DGEBA resins have low adherence to carbon fibers, resulting in the development of other epoxy compounds: tetraglycidyl-4,4'-methylenedianiline (TGMDA), triglycidyl *p*-aminophenol (TGPAP),

^a MD/MS Clinical Research Scholars Program, Case Western Reserve University School of Medicine, 2109 Adelbert Road, Cleveland, OH 44106, USA

^b Department of Dermatology, Dermatology-Plastic Surgery Institute, Cleveland Clinic Foundation, A-61, 9500 Euclid Avenue, Cleveland, OH 44195, USA

* Corresponding author.

E-mail address: taylorj@ccf.org (J.S. Taylor).

Box 1

Synthetic plastic resin systems which cause allergic and irritant contact dermatitis

- Epoxy
- (Meth)acrylic
- Polyurethane
- Phenol-formaldehyde
- Polyester
- Amino resin
 - Melamine-formaldehyde
 - Urea-formaldehyde
- Polyvinyl
- Polystyrene
- Others
 - Polyolefin
 - Polyamide
 - Polycarbonate

Box 2

Epoxy resin system additives

- Antioxidants
- Colorants
- Fillers/reinforcement agents (eg, carbon, glass, nylon fibers)
- Flame retardants
- Hardeners (curing agents)
- Initiators
- Melamine formaldehyde resins
- Metallic compounds
- Phenol-formaldehyde resins
- Plasticizers
- Reactive diluents
- Solvents
- Tar
- Urea formaldehyde resins
- Ultraviolet light absorbers

Data from Bjorkner B, Ponten A, Zimerson E, et al. Plastic materials. In: Frosch PJ, Menné T, Lepoittevin JP, editors. Contact dermatitis, 4th edition. Berlin: Springer Verlag; 2006. p. 583–621; and Taylor JS. Occupational dermatoses. Alderman MH, Hanley MJ, editors. Clinical medicine for the occupational physician. New York: Marcel Dekker, Inc; 1982. p. 299–344.

and o-diglycidyl phthalate.^{1,4,5} Additionally, instead of bisphenol A, bisphenol F may be used to manufacture the 3 isomers of diglycidyl ether of bisphenol F (DGEBF), which may be mixed with DGEBA resins to increase physical (eg, heat) and chemical resistance.⁶

Epoxy resins have properties such as easy curing, low shrinkage, excellent adhesiveness, high physical strength and resistance, and great electrical resistance, which make them ideal candidates for diverse commercial applications.⁷ World production of epoxy resins totals around 1 million tons annually, of which 40% to 50% are used in protective surface coatings and adhesives (eg, paints and lacquers; laminates; electric insulation and encapsulation; floor covering; molding; corrosion protection of metals; castings for metal tools; mending of cracks and fissures in concrete; and glues for metal, plastics, rubber, wood, glass, and ceramics).^{1,2,8,9} Epoxy resins are also used in other products, such as electronic circuit boards, filling agents, printing inks, polyvinyl chloride products, and immersion oil for microscopes.^{1,2,9,10}

The most frequent adverse cutaneous effects from ERSs are ACD and ICD, most of which arise in the occupational setting during production of epoxy resins or manipulation of finished epoxy products.^{1–3,7,9–12} Nevertheless, there have been occasional reports of nonoccupational causes of epoxy resin contact dermatitis, such as from hobby glues and residues of unhardened resin on coated objects (eg, knee patches, bottle caps, film cassettes, metal packages) (Fig. 1).^{13,14} A Finnish study revealed that ERS compounds (DGEBA, hardeners, reactive diluents) were the third most common cause (12.1%) of currently relevant occupational ACD, and accounted for 0.8% of occupational ICD cases.¹⁵ Another Finnish study reported that ERS compounds were responsible for 7.7% of occupational skin disease: Of the 142 patients with ERS-induced occupational dermatoses, 135 (95%) had ACD, 5 (4%) had ICD, and 2 (1%) had contact urticaria.¹⁶ Analyzing data from the Register of Occupational Skin Diseases in Northern Bavaria, Dickel and colleagues⁸ found that epoxy resin was the second most common (67%) occupationally relevant sensitizer. A fourth study of a group of Norwegian industrial painters revealed an incidence rate of 4.5 per 1000 person years for ACD caused by ERS compounds.¹⁷ The prevalence of ACD or sensitization to ERS chemicals has been reported for various occupations: ACD to ERS chemicals was found to be 45% in marble workers¹⁸ and 18% in construction workers.¹⁹ Sensitization to ERS chemicals upon patch testing

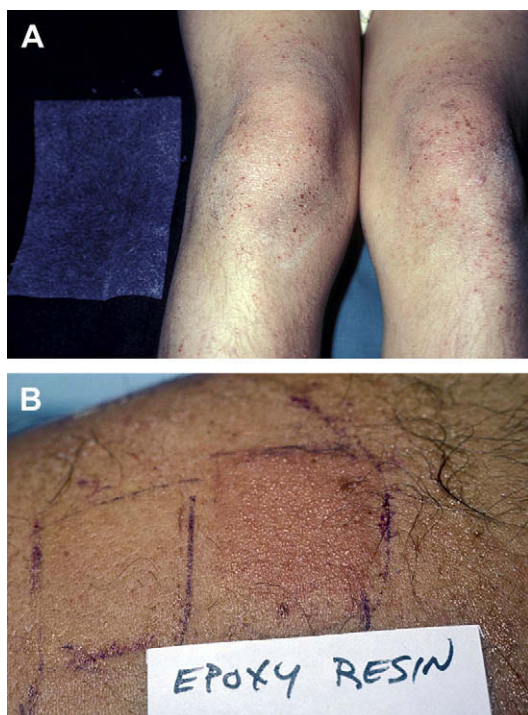


Fig. 1. Allergic contact dermatitis of the knees from epoxy resin which was demonstrated to be present in the knee patch of this boy's jeans (A). Patch testing with epoxy resin yielded a positive reaction (B).

was demonstrated to be 56% in aircraft manufacturing workers,⁵ 27% in ski factory workers,²⁰ 21% in paint manufacturing workers,²¹ and 20% in construction workers.¹⁹ However, some of these studies did not include patch tests with ERS hardeners or reactive diluents, which means that the actual prevalence of sensitization to ERS chemicals may be even higher. Other occupations with common exposures and sensitizations to ERS compounds are outlined in **Box 3**.

ACD sensitization is generally caused by low-MW or short-chain chemicals.^{7,23} Fregert and Thorgeirsson demonstrated that whereas all 34 of their epoxy resin-sensitized patients reacted to the MW 340 oligomer of DGEBA epoxy resin upon patch testing, none reacted when tested with the higher MW oligomers.²³ The sensitizing potential of epoxy resin decreases as the average MW increases.²³ However, other investigators have indicated that DGEBA epoxy resins with higher average MW are potential sensitizers, especially with simultaneous exposure to skin irritants such as organic solvents and amine hardeners.¹⁶ Exposure to paints and their raw materials, surface coatings, and adhesives has been reported to be the most common cause of occupational

Box 3

Occupations with frequent exposures to epoxy resin system compounds

Adhesive and glue manufacturing
 Aircraft manufacturing
 Appliance finishing
 Assembling
 Automobile manufacturing
 Boat manufacturing
 Can coating
 Cement work
 Ceramics
 Construction and building
 Electric insulation
 Electronics
 Floor covering
 Furniture building
 Lacquering
 Laminating
 Laboratory work with microscope immersion oil
 Machining
 Marble work
 Metal casting
 Other plastic material (eg, polyvinyl chloride) manufacturing
 Paint, lacquer, and varnish manufacturing
 Painting
 Printing ink manufacturing
 Sculpting
 Sporting equipment manufacturing (eg, tennis rackets, skis)
 Soldering
 Terrazzo work
 Tile setting
 Tunnel work
 Varnishing
 Wood processing

Data from Refs. ^{1,2,8–10,22}

dermatoses induced by ERSs.¹⁶ The most frequent causes of ERS-induced ACD are epoxy resins,^{21,23,24} which together induced 93% of all ERS dermatoses in one study.¹⁶ Approximately 60% to 80% of patients with ACD to epoxy resins

are sensitized to DGEBA,¹ the most common cause of contact allergy to ERS compounds,¹⁶ but other epoxy resins are also capable of sensitization (**Box 4**). Significant cross-reactivity has been noted between DGEBA and DGEBF owing to structural similarity.²⁵ According to Jolanki, hardeners are the second most common cause of contact allergy induced by ERS compounds (**Box 5**).¹⁶ Jolanki identified reactive diluents as the fourth most common cause of ERS-induced ACD after DGEBA epoxy resins, hardeners, and non-DGEBA epoxy resins.¹⁶ Reactive diluents noted to induce contact allergy are presented in **Box 6**. Cross-sensitization between reactive diluents has been reported to be common.¹⁶ Other additives in ERSs, such as epoxy accelerators containing hexavalent chromate, are capable of causing ACD as well.^{26,27}

ICD is a less common form of ERS-induced occupational contact dermatitis, and has been reported with high-MW DGEBA epoxy resins (average MW above 700), hardeners (eg, polyamines, methyl hexahydrophthalic anhydride [MHHPA]), and carbon or glass fiber fragments which are mixed with epoxy resins.^{15,16,31} Rarely, contact urticaria has been noted with use of DGEBA resins and aliphatic polyamine and anhydride (eg, methylhexahydrophthalic anhydride, methyltetrahydrophthalic anhydride) hardeners,^{24,32} and photoallergic contact dermatitis has been reported with heating of DGEBA resins, possibly owing to the bisphenol A component.³³ IgE-mediated occupational asthma induced by epoxy resins has additionally been reported.³⁴

Because sensitization is usually observed in workers who handle uncured epoxy resins, the hands, forearms, face, and neck are predominantly affected by dermatitis, with the face and neck involved through indirect contact with hands or airborne exposure.^{8,15,35} ICD presents with a similar pattern of distribution.^{15,16,31} Airborne exposure resulting in ACD or ICD of the face,

Box 4
Types of epoxy resins

- Diglycidyl ether of the bisphenol A (DGEBA)
- Diglycidyl ether of the bisphenol F (DGEBF)
- Brominated
- Cycloaliphatic
- Heterocyclic dimethyl hydantoin
- Phenol novolak

Data from Refs. ^{6,16,22,28}

Box 5
Epoxy resin system hardeners reported to cause contact allergy

- Aliphatic polyamines
 - Diethylenetriamine (DETA)
 - 3-Dimethylaminopropylamine
 - Ethylenediamine (EDA)
 - Hexamethylenetetramine
 - Triethylenetetramine (TETA)
 - Trimethylhexamethylenediamine (TMDA)
- Cycloaliphatic polyamines
 - 3,3'-Dimethyl-4,4-diaminodicyclohexylmethane
 - Isophoronediamine (IPDA)
- Aromatic amines
 - 4,4'-Diaminodiphenylmethane (MDA)
 - 2,4,6-tris-Dimethylaminomethyl phenol (tris-DMP)
 - m-Phenylene diamine
 - 1,3-Xylylene diamine
- Anhydrides
- Dicyanodiamide
- Triglycidyl isocyanurate

Data from Refs. ^{16,22,29}

eyelids, and neck is more likely to occur with hardeners and reactive diluents, which are more volatile than epoxy resins themselves.³⁶ Nevertheless, even in cured ERSs, up to 25% of epoxy resin monomers may be unhardened and capable of eliciting ACD in previously sensitized individuals, especially when cured at room temperature.¹ Moreover, when there are unexplained patch test reactions to epoxy resins, it is important to inquire about the occupations of family and friends, because the patient may have a connubial or consort dermatitis (ie, “epoxy-by-proxy”).³⁷

When ERS-induced ACD is suspected by the patient’s history and cutaneous findings, patch testing with low-MW epoxy resin containing high amounts of DGEBA oligomer MW 340 (1% in petrolatum), as included in most standard series, is adequate in most cases to detect sensitization. When other components of ERSs, such as other epoxy resins, hardeners, and reactive diluents, are potential culprits, patch testing to these ERS chemicals with appropriate concentrations has been recommended (**Table 1**). In some cases, it

Box 6**Epoxy resin system reactive diluents reported to cause contact allergy**

Allyl glycidyl ether (AGE)
 1,4-Butane-diol diglycidyl ether (BDDGE)
n-Butyl glycidyl ether (BGE)
 Cresyl glycidyl ether (CGE)
ortho-Cresyl glycidyl ether (*ortho*-CGE)
 Cyclohexanedimethanol glycidyl ether
 Diethyleneglycol diglycidyl ether
p-Fluorophenyl glycidyl ether
 Glycidyl ester of synthetic fatty acids
 Glycidyl ether of aliphatic alcohols
 1,6-Hexanediol diglycidyl ether (HDDGE)
 α -Naphthyl glycidyl ether
 Neopentyl glycol diglycidyl ether (NPGDGE)
 Phenyl glycidyl ether (PGE)
m-Xylene diamine

Data from Refs. ^{16,18,20,22,30}

may be necessary to patch test with an appropriate dilution of the patient's own resin, products obtained from the patient's work environment, or samples acquired directly from the manufacturer. Workers found to be sensitized to ERS components should be instructed to employ a no-touch technique and to try to avoid as much exposure as possible; and in some cases, they may need to change jobs. Immediate transfer of workers sensitized to epoxy resins may prevent aggravation of their contact dermatitis and broadening of sensitizations to other ERS components such as hardeners and reactive diluents.¹⁹ To reduce the sensitization potential of DGEBA epoxy resins, the use of low-MW 340 and MW 624 oligomers should be kept at a minimum and their concentrations should be specified on product labels.^{22,23} Hardeners should not contain remains of aliphatic polyamines, and reactive diluents should be high (>1000) MW.²²

(METH)ACRYLIC RESINS

(Meth)acrylic resins are formed by various combinations of the monomers acrylic acid and its esters, methacrylic acid and its esters, cyanoacrylic acid and its esters, acrylamides and acrylonitrile, during which initiators, accelerators, catalysts, electron beams, ultraviolet (UV) light, or visible light are used to speed up the process.¹

(Meth)acrylic resins have a diverse array of uses (**Box 7**). Various groups of (meth)acrylics include mono(meth)acrylics, which have 1 functional acrylic group; multifunctional (meth)acrylics, which have 2 or more reactive acrylic groups; epoxy (meth)acrylics (eg, 2,2-bis[4-(2-hydroxy-3-methacryloxypropoxy)phenyl]propane [BIS-GMA]), which are derived from reacting epoxy resins or glycidyl derivatives with acrylic acid; urethane (meth)acrylics, which combine aromatic or aliphatic isocyanates with acrylic acid; and polyester (meth)acrylics.¹ **Table 2** lists the (meth)acrylics which are commonly used in artificial nails, dental materials, UV cured inks, coatings, paints and lacquers, and anaerobic adhesives, along with their recommended patch test concentrations.

There have been numerous animal reports on the sensitization potentials of various (meth)acrylics. Guinea pig studies have revealed that the addition of a methyl group to the alpha-carbon atom of acrylic groups appears to decrease their sensitization potential. Monoacrylics are strong sensitizers, whereas monomethacrylics are weak to moderate sensitizers.^{1,39,47,48} Likewise, whereas di- and tri-acrylics are potent sensitizers, the multifunctional methacrylics are weak or nonsensitizers.⁴⁹ Of the epoxy (meth)acrylics, 2,2-bis-(4-(2-hydroxy-3-acryloxy-propoxy)phenyl)propane (epoxy diacrylate), 2,2-bis-(4-(2-methacryloxyethoxy)phenyl)propane (BIS-EMA) and 2,2-bis-(4-(methacryloxy)phenyl)propane (BIS-MA) have been demonstrated to be strong sensitizers, whereas the linear fraction of BIS-GMA and its isomers and 2,2-bis-(4-(3-methacryloxy-propoxy)phenyl)propane (BIS-PMA) have little or no sensitizing capacity.⁵⁰ Sensitization appears to be caused by the entire epoxy (meth)acrylic molecule, although free epoxy resin oligomer MW 340 may also sensitize.⁵¹ Aliphatic urethane (meth)acrylics appear to be more potent sensitizers than aromatic ones, and aliphatic urethane methacrylics seem to have lower contact allergenicity than corresponding aliphatic urethane acrylics.⁵² However, the author cautioned that whether these generalizations apply to all aliphatic and aromatic urethane (meth)acrylics merits further investigation.⁵² The whole polyester (meth)acrylic structure appears to be a contact allergen, although polyester and (meth)acrylate have also been shown to be moderate sensitizers.⁵³

Although (meth)acrylic-induced asthma and rhinoconjunctivitis have been reported,⁵⁴ the principal health problems from (meth)acrylic resins are cutaneous diseases (eg, contact dermatitis), and these occur both occupationally⁵⁵ and in consumers using end products.^{39,43}

Table 1
Recommended patch test concentrations for epoxy resin system chemicals

Epoxy Resin System Chemicals	Patch Test Concentration (% in Petrolatum)
Epoxy resins	
Diglycidyl ether of the bisphenol A (DGEBA)	1
Diglycidyl ether of the bisphenol F (DGEBF)	1
Amine hardeners	
4,4'-Diaminodiphenylmethane (MDA)	0.5
Diethylenetriamine (DETA)	1
Ethylenediamine (EDA)	1
Hexamethylenetetramine	1–2
Isophoronediamine (IPDA)	0.5
Triethylenetetramine (TETA)	0.5
Reactive diluents	
Allyl glycidyl ether (AGE)	0.25
1,4-Butane-diol diglycidyl ether (BDDGE)	0.25
<i>n</i> -Butyl glycidyl ether (BGE)	0.25
<i>Ortho</i> -Cresyl glycidyl ether (<i>ortho</i> -CGE)	0.25
Glycidyl ester of synthetic fatty acids	0.25
Glycidyl ether of aliphatic alcohols	0.25
1,6-Hexanediol diglycidyl ether (HDDGE)	0.25
Neopentyl glycol diglycidyl ether (NPGDGE)	0.25
Phenyl glycidyl ether (PGE)	0.25
Other chemicals	
Bisphenol A	1
Epichlorohydrin	0.1–0.3
2,2-Bis[4-(2-hydroxy-3-methacryloxypropoxy)phenyl]propane (BIS-GMA)	2
2,2-Bis[4-(methacryloxy)phenyl]-propane (BIS-MA)	2

Data from Rietschel RL, Fowler JF. *Plastics, adhesives and synthetic resins*. In: Rietschel RL, Fowler JF, editors. *Fisher's contact dermatitis*, 6th edition. Hamilton (ON): BC Decker Inc; 2008. p. 542–65. and de Groot AC, Frosch PJ. *Patch test concentrations and vehicles for testing contact allergens*. In: Frosch PJ, Menné T, Lepoittevin JP, editors. *Contact dermatitis*, 4th edition. Berlin: Springer Verlag; 2006. p. 907–28.

Mono(meth)acrylics and multifunctional (meth)acrylics have frequently been noted to cause sensitizations and ACD. Because of cross-reactivity, sensitized persons will often have contact allergic reactions to many other (meth)acrylic compounds.^{56–58} Other less frequent presentations include paronychia, nail dystrophy, onycholysis (Fig. 2), and paresthesias.^{59–62} Contact allergy from artificial nails has been reported with methyl methacrylate, which was banned from use in the United States in 1974.³⁹ Since then, other mono-methacrylics have been used in nails, such as ethyl methacrylate, butyl methacrylate, and methacrylic acid, which may be even stronger sensitizers.^{39,62} 2-Hydroxyethyl methacrylate (2-HEMA) and 2-hydroxypropyl methacrylate (2-HPMA) are other common mono(meth)acrylic contact allergens in

artificial nails.^{60,63} Dimethacrylics, such as ethylene glycol dimethacrylate (EGDMA) and triethylene glycol dimethacrylate (TREGDMA), are among the most common multifunctional (meth)acrylic allergens found in artificial nails.^{39,60,63} ACD from artificial nails usually involves the hands and fingers, with dermatitis being the most common presentation.⁶⁰ It was shown in one study that involvement of dorsal hands, fingers, forearms, face, and neck through direct contact in beauticians owing to occupational exposures was more frequent than in consumers.⁶⁰ Workers and consumers should be educated to use no-touch techniques before the mono(meth)acrylics in the artificial nails are polymerized.³⁹

Because most composite materials used in dentistry today contain resins based on

Box 7**(Meth)acrylics: uses and potential exposures****Beauty products**

Artificial nails, nail polishes, hair sprays, fragrances, dentifrices, insecticides

Construction materials

Adhesives, paints, sealers and stoppers, concrete additives

Medical uses

Dentures and other dental materials, artificial eye lens implants, orthopedic prostheses, heart valves, artificial joints, contact lenses, eyeglasses, hearing aids, adhesive plasters, wound sprays, infusion systems, splints

Printing uses

Ultraviolet cured inks, photopolymer and flexographic printing plates

Textiles

Synthetic fibers, finishes (eg, on leather)

Utensils

Synthetic rubbers, acrylic glass (Plexiglas), veneers

Other uses

Ultraviolet cured coatings, paints, glues, plastic foams, molecular sieves, gel electrophoresis, low temperature embedding media for electron microscopy, lubricant additives, aircraft windows, highway reflectors, glass, mineral sedimentation, water purification, soil improvers, synthesis of other plastics

Data from Refs. ^{1,2,22,46}

primarily presents as ACD on the first 3 fingers and may induce onycholysis.⁶⁶

Among those working with photoprepolymer printing plates and UV cured inks, coatings, paints, and lacquers, 2-HEMA and 2-HPMA are common causes of contact allergy.^{41,42} Contact allergy to multifunctional di- and tri-acrylics (eg, pentaerythritol triacrylate [PETA], trimethylol propane triacrylate [TMPTA], 1,6-hexanediol diacrylate [HDDA]) has been reported to be especially prevalent in those exposed to UV cured inks and coatings.⁴³

Epoxy (meth)acrylics are rather unusual sensitizers in humans.^{56,67} Likewise, few reports on contact allergy from urethane (meth)acrylics have been published.^{68,69}

When patch testing with (meth)acrylic compounds, use of petrolatum as the test vehicle in a plastic test chamber is recommended, because false negatives have occurred from acetone and alcohol vehicles and aluminum chambers owing to induction of rapid polymerization of (meth)acrylic monomers.⁷⁰ In general, methacrylic monomers should be patch tested at 2% in petrolatum, and acrylic monomers should be tested at 0.1% in petrolatum to avoid patch test sensitizations.^{1,38}

ICD has been reported with various (meth)acrylic use.^{43,47,64,71,72} A study among dental technicians reported that whereas fingertips were primarily involved in ACD, ICD occurred mostly on dorsa of the fingers (especially of the dominant hand).⁶⁴ Studies in guinea pigs have revealed diacrylics to be strong irritants, monoacrylics to be weak to moderate irritants, and mono- or di-methacrylics to have little or no sensitizing potential.^{1,47}

POLYURETHANE RESINS

Polyurethanes are generally formed from reacting isocyanates with polyhydroxy compounds (eg, polyesters, polyethers, water, amines), in the presence of appropriate catalysts and additives (**Box 8**).^{1,2} Isocyanates are low-MW aromatic, aliphatic, or cycloaliphatic compounds with a highly reactive $-N=C=O$ functional group.^{1,73} Aromatic diisocyanates, especially diphenylmethane diisocyanate (MDI) and toluene diisocyanate (TDI), are most commonly used. Industrial applications include acting as rubber substitutes in the manufacturing of foam used for mattresses, cushions, dashboards, packages, insulation, and Spandex; use in coatings, paints, lacquers, adhesives, binders, castings, elastomers, and fibers; and use in industries such as construction, furniture production, automobile manufacturing, electronics, shoe manufacturing, and health

methacrylics,^{50,52} contact allergy to mono- and multifunctional methacrylics (eg, 2-HEMA, methyl methacrylate, EGDMA, TREGDMA) is often seen in dental personnel and patients.^{40,63} One study reported that screening for (meth)acrylic contact allergy with 2-HEMA alone picked up 96.7% of (meth)acrylic-allergic dental patients and 100% of (meth)acrylic-allergic dental personnel, and the addition of bis-GMA increased the detection rate of (meth)acrylic-allergic dental patients to 100%.⁴⁰ Fingertip dermatitis is common among dental personnel.⁶⁴

Additionally, mono- and multifunctional methacrylics (eg, 2-HEMA, 2-HPMA, EGDMA, TREGDMA, tetrahydrofurfuryl methacrylate) frequently cause contact allergy in those working with anaerobic acrylic adhesives and sealants (**Fig. 3**),^{44,63,65} which

Table 2
Commonly used (meth)acrylic monomers in selected commercial products and their recommended patch test concentrations

Commercial Use	Commonly Used (Meth)Acrylic Monomers	Patch Test Concentration (% in Petrolatum)
Artificial nails	Butyl methacrylate	2
	Diethylene glycol dimethacrylate (DEGDMA)	2
	Ethyl acrylate	0.1
	Ethylcyanoacrylate (ECA)	5
	Ethylene glycol dimethacrylate (EGDMA)	2
	Ethyl methacrylate	2
	2-Hydroxyethyl acrylate (2-HEA)	0.1
	2-Hydroxyethyl methacrylate (2-HEMA)	2
	Isobutyl methacrylate	2
	Methyl acrylate	0.1
	Methacrylic acid	1
	Methyl methacrylate	2
	Tetrahydrofurfuryl methacrylate (THFMA)	2
	Triethylene glycol diacrylate (TREGDA)	0.1
	Triethylene glycol dimethacrylate (TREGDMA)	2
	Trimethylol propane trimethacrylate (TMPTMA)	2
	Tripropylene glycol acrylate	0.1
	Tripropylene glycol diacrylate (TPGDA)	0.1
	Urethane methacrylate	2

Dental materials

Benzaldehyde glycol methacrylate	2
Biphenyl dimethacrylate	2
2,2-Bis[4-(2-hydroxy-3-methacryloxypropoxy)phenyl]propane (BIS-GMA)	2
2,2-Bis[4-(2-methacryloxyethoxy)-phenyl]-propane (BIS-EMA)	1
2,2-Bis[4-(methacryloxy)phenyl]-propane (BIS-MA)	2
2,2-Bis[4-(3-methacryloxypropoxy)phenyl]-propane (BIS-PMA)	N/A
1,4-Butanediol dimethacrylate (BUDMA)	2
1,3-Butyleneglycol diacrylate	0.1
Butyl methacrylate	2
1,10-Decanediol dimethacrylate	2
Diethylene glycol dimethacrylate (DEGDMA)	2
2-(Dimethylamino)ethyl methacrylate	2
3,6-Dioxaoctamethylene dimethacrylate	2
1,12-Dodecanediol dimethacrylate	2
Epoxy methacrylates	2
Ethylene glycol dimethacrylate (EGDMA)	2
Ethyl methacrylate	2
Glycerol phosphate dimethacrylate	2
1,6-Hexanediol diacrylate (HDDA)	0.1
2-Hydroxyethyl methacrylate (2-HEMA)	2
Methyl methacrylate	2
Phenylsalicylate glycidyl methacrylate	2
Tetrahydrofurfuryl methacrylate (THFMA)	2
<i>n</i> -Tolylglycine-glycidylmethacrylate	2
Triethylene glycol dimethacrylate (TREGDMA)	2
Trimethylol propane trimethacrylate (TMPTMA)	2
Urethane dimethacrylate	2

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Table 2
(continued)

Commercial Use	Commonly Used (Meth)Acrylic Monomers	Patch Test Concentration (% in Petrolatum)
Ultraviolet cured inks, coatings, paints, and lacquers	Butyl acrylate	0.1
	Diethylene glycol diacrylate (DEGDA)	0.1
	Dipropylene glycol diacrylate (DPGDA)	0.1
	Epoxy acrylates	0.5
	2-Ethyl-hexyl acrylate (2-EHA)	0.1
	1,6-Hexanediol diacrylate (HDDA)	0.1
	2-Hydroxyethyl acrylate (2-HEA)	0.1
	2-Hydroxyethyl methacrylate (2-HEMA)	2
	2-Hydroxypropyl acrylate (2-HPA)	0.1
	2-Hydroxypropyl methacrylate (2-HPMA)	2
	Pentaerythritol triacrylate (PETA)	0.1
	Polyester acrylates	0.1
	Trimethylol propane triacrylate (TMPTA)	0.1
	Tripropylene glycol diacrylate (TPGDA)	0.1
	Tripropylene glycol triacrylate (TPGTA)	0.1
	Urethane acrylates	0.1
Anaerobic adhesives	Diethylene glycol diacrylate (DEGDA)	0.1
	Epoxy diacrylate	0.5
	Ethylcyanoacrylate (ECA)	5
	Ethylene glycol dimethacrylate (EGDMA)	2
	2-Hydroxyethyl methacrylate (2-HEMA)	2
	2-Hydroxypropyl methacrylate (2-HPMA)	2
	Methyl methacrylate	2
	Polyethylene glycol dimethacrylate (PEGDMA)	2
	Tetraethylene glycol dimethacrylate (TETEGDMA)	2
	Tetrahydrofurfuryl methacrylate (THFMA)	2
	Triethylene glycol diacrylate (TREGDA)	0.1
	Triethylene glycol dimethacrylate (TREGDMA)	2

N/A, not available.

Data from Refs. ^{1,38-45}

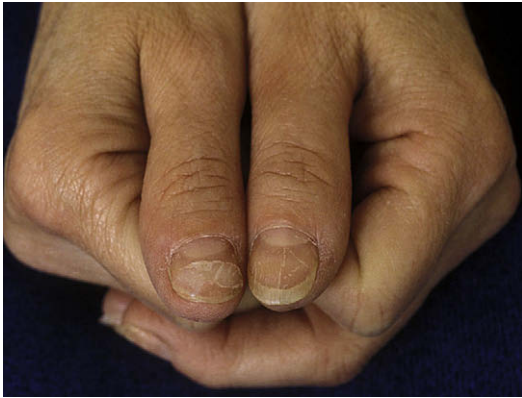


Fig. 2. Patient with onycholysis caused by acrylic nails.

care.^{1,2,74} However, because aromatic diisocyanates undergo oxidative discoloration when exposed to light and moisture, aliphatic diisocyanates (eg, 1,6-hexamethylene diisocyanate [HDI], isophorone diisocyanate [IPDI]) are used instead in these applications, and are often found in paints, lacquers, and coatings.¹ In industry, these diisocyanates are often made into higher MW polyisocyanates to reduce their volatility.^{1,75} Other examples of diisocyanates used industrially are shown in **Box 9**.

Although isocyanates in polyurethane resins primarily cause respiratory and other mucosal

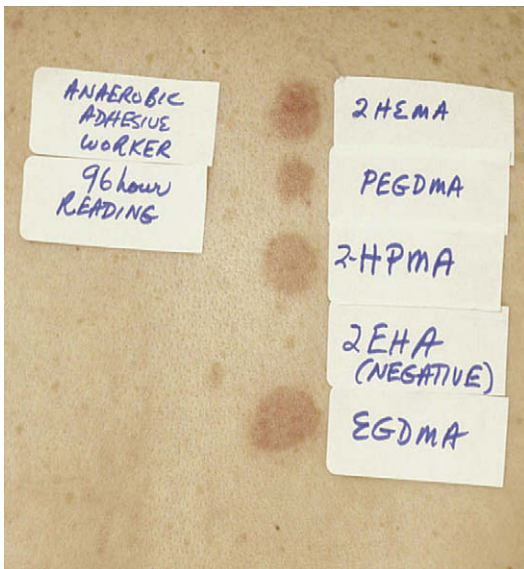


Fig. 3. Positive patch test reactions to several acrylics in an anaerobic adhesive worker. *Abbreviations:* 2-HEMA, 2-hydroxyethyl methacrylate; PEGDMA, polyethyleneglycol dimethacrylate; 2-HPMA, 2-hydroxypropyl methacrylate; 2-EHA, 2-ethylhexyl acrylate (negative); EGDMA, ethyleneglycol dimethacrylate.

Box 8

Polyurethane resin system additives

- Antioxidants
- Biocides
- Blowing agents (eg, pentane, carbon dioxide, water)
- Coloring agents
- Cross-linking agents
- Fillers
- Fire retardants
- Hardening catalysts (eg, tertiary amines, tin)
- Initiators
- Metallic compounds
- Plasticizers
- Ultraviolet light absorbers

Data from Bjorkner B, Ponten A, Zimerson E, Frick M. Plastic materials. In: Frosch PJ, Menné T, Lepoittevin JP, editors. Contact dermatitis, 4th edition. Berlin: Springer Verlag; 2006. p. 583–621.

diseases, such as asthma, rhinitis, conjunctivitis, bronchial hyperreactivity, hypersensitive pneumonitis, extrinsic allergic alveolitis, and chronic obstructive lung diseases,^{76,77} they may also induce ICD, ACD, and contact urticaria, which typically present on the hands and face.^{1,73} Isocyanates appear to induce more ICD than ACD, and have been reported as mild to strong irritants.^{1,78–81} Amine accelerators used in polyurethanes, such as diaminodiphenyl methane

Box 9

Commonly used diisocyanates in industry

- Diphenylmethane diisocyanate (MDI)
- Toluene diisocyanate (TDI)
- 1,6-Hexamethylene diisocyanate (HDI)
- Isophorone diisocyanate (IPDI)
- Dicyclohexylmethane diisocyanate (DMDI)
- Naphthalene diisocyanate (NDI)
- Trimethyl hexamethylene diisocyanate (TMDI)
- Triphenylmethane triisocyanate (TPMTI)

Data from Bjorkner B, Ponten A, Zimerson E, Frick M. Plastic materials. In: Frosch PJ, Menné T, Lepoittevin JP, editors. Contact dermatitis, 4th edition. Berlin: Springer Verlag; 2006. p. 583–621; and Estlander T, Keskinen H, Jolanki R, et al. Occupational dermatitis from exposure to polyurethane chemicals. Contact Dermatitis 1992;27(3):161–5.

(MDA), triethylenediamine and triethylamine, are also skin irritants.¹ Diisocyanates, including MDI, TDI, HDI, and dicyclohexylmethane diisocyanate (DMDI) have been shown to be strong contact sensitizers in mice, with cross-reactions occurring between aromatic and aliphatic diisocyanates.^{82–84} There have also been reports of contact sensitizations and ACD from isocyanates in humans, mostly occupational cases^{73,74,81,85–90} but some in consumers,^{91–94} although these reports have been few and sporadic considering isocyanates' ubiquitous uses; this is likely because of extensive worker protections from the harmful effects of polyurethanes on the respiratory and other mucosal systems.¹ Contact sensitizations and ACD have been noted with MDI, TDI, HDI, IPDI, DMDI, and trimethyl hexamethylene diisocyanate (TMDI).^{73,74,81,85–92} Many studies have reported simultaneous positive reactions to MDI and MDA (an aromatic diamine used as a hardener in epoxy and polyurethane resins, as an antioxidant in rubber production, and in insecticides and germicides).^{73,74,85,86,88–90,95} Fregert first noted the simultaneous reactions to MDI and MDA, and attributed this to cross-reaction.^{90,95} Another explanation was proposed by Rothe⁹⁶ in 1976: MDA may be the allergen and is formed from hydrolysis of MDI when MDI contacts the skin.⁹⁰ Indeed, later reports confirm that positive patch test reactions can occur only to MDA, and not to the isocyanates with which patients had come in contact.^{90,97} MDA may also co-react with numerous other substances such as para-phenylenediamine, cobalt, fragrance mix, paraben mix, and benzocaine.⁹⁸ Furthermore, rare instances of isocyanates inducing contact urticaria have been reported.^{99,100}

Although fully cured polyurethane products generally do not cause dermatitis, there are other circumstances where skin problems arise. Firstly, isocyanate products which are not fully cured represent a source of skin exposure.¹⁰¹ Bello and colleagues¹⁰¹ demonstrated that curing is a slower process than expected—unbound isocyanate species were detected on painted surfaces for a few days to a month. Hence, recently cured isocyanate products are another potential cause of dermatitis. Moreover, release of free isocyanates may occur during heating of cured isocyanate products, such as during machining, cutting, grinding, or sanding such products.^{102,103}

When contact allergy to polyurethane resins is suspected, patients should be tested with relatively fresh preparations of common diisocyanates—4,4'-MDI and 2,4-TDI at 1.5% to 2% in petrolatum, HDI, IPDI, and 4,4'-DMDI. They should

also be patch tested to MDA 0.25% in petrolatum (although some true positives may be missed, active sensitization with MDA 0.5% in petrolatum has been reported).^{73,104,105} A late reading at day 7 may be needed to detect positive reactions to isocyanates (eg, MDI), and patients should be instructed to report reactions that appear after day 7.^{90,104} Amines of isocyanates (eg, MDA) appear to serve as good markers for detecting isocyanate sensitization.⁸⁶ Although Estlander and colleagues⁷³ had suggested that MDI and TDI test preparations may be used for over a year because preparations which were 5.5 and 15.5 months old had elicited positive patch test reactions, Frick and colleagues¹⁰⁶ performed chemical analyses which showed that commercially available patch test preparations of MDI contained concentrations lower than those stated on labels, even before expiry dates, risking false negative reactions during patch testing. Hence, patch testing with the patient's own fresh occupational or consumer products, diluted as necessary, is sometimes needed for detecting polyurethane resin contact allergies which may be missed by standard patch testing.^{90,106}

PHENOL-FORMALDEHYDE RESINS

Phenol-formaldehyde resins (PFRs) are formed by the combination of phenols (eg, phenol, bisphenol A, *p*-*tert*-butylphenol) and aldehydes (especially formaldehyde, but also acetaldehyde, glyoxal).¹ These resins were the first plastics to be made on a large scale in the United States and were often used as casting compounds.^{2,8} However, their use has declined over the years: Today, because of their adhesive power, durability, heat resistance, and elasticity, PFRs and *p*-*tert*-butylphenol-formaldehyde resin (PTBFR) are used mainly as glues and adhesives in the paint and varnish, decorative laminate, rubber, building, plywood, construction, automobile, aircraft, boating, shoe, artificial nail, leather, and electronic (for insulation) industries.^{8,107,108}

The adverse effects of handling PFRs are mostly cutaneous (ie, contact dermatitis), of which a higher proportion is ACD than ICD, which may occur on the hands and face (from occupational exposure) or feet (from shoes).^{109,110} These generally occur in the occupational setting,^{8,111} although non-occupationally-induced dermatitis may develop as a result of hobby work or exposure to unpolymerized monomers or dimers left in the finished products (eg, shoes, clothing, watch band, adhesive label, athletic tape) (Figs. 4 and 5).^{107,110–113}

Most reports of contact dermatitis are because of PTBFR sensitization. In an analysis of patch

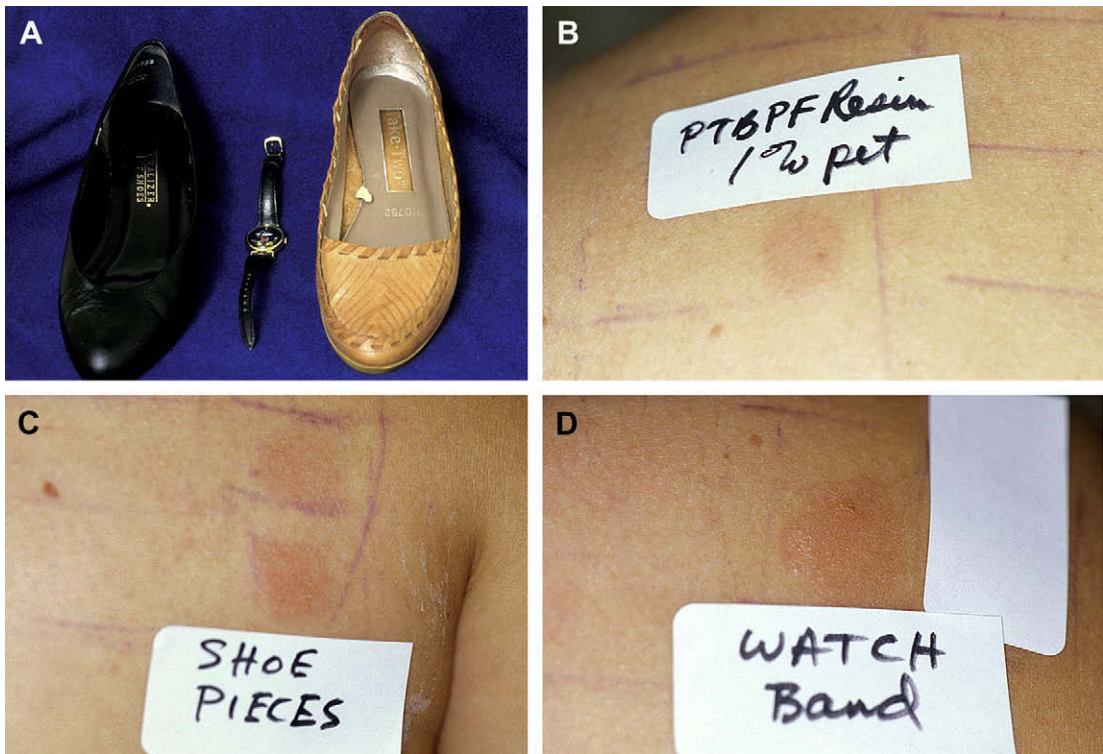


Fig. 4. Shoe and watch band allergy in a patient with foot and wrist dermatitis (A). Patient had positive patch test reactions to the adhesive *p*-tert-butylphenol-formaldehyde resin (PTBFR) (B) and to thin pieces of 2 shoes (C) and a watch band (D) which likely contained PTBFR.

test results with the plastics and glues series, Tarvainen found that PTBFR was the most common contact allergen.¹¹¹ Similar reports of sensitizations and ACD induced by PTBFR have been made.^{107,108,110,114–118} As noted by Fousseau and colleagues,¹¹⁷ occupational contact allergies to PTBFR represent 71% of cases, and footwear and clothing allergies to PTBFR account for the other 29%. Positive reactions may be caused by the resin itself (especially when unhardened or incompletely hardened), or less frequently by *p*-tert-butylphenol and formaldehyde.^{2,108,117–119} A number of substances in PTBFR have been found to be contact allergens from human and guinea pig studies (Box 10). Guinea pigs sensitized to 2,6-dimethylol *p*-tert-butylphenol (2,6-MMPTBP) showed cross-reactions to 2-methylol *p*-tert-butylphenol (2-MPTBP) and *p*-tert-butylcatechol.¹²⁰ The strong sensitizer *p*-tert-butylcatechol has been noted to be present in PTBFR, but also is used as a stabilizer in the production of other plastic monomers.^{1,121} Human and guinea pig studies have demonstrated cross-reactions between *p*-tert-butylcatechol when tested with *p*-tert-butylphenol.^{121,122}

Although there are fewer reports on ACD induced by other PFRs,^{126,127,128} allergens in these resins have been noted as well (Box 11). Monomers have weaker allergenic potentials than dimers.¹⁰⁸ Of the dimers, the 4,41-dihydroxydiphenyl methanes have been shown in guinea pigs to be the most potent contact allergens.¹⁰⁸ Potential cross-reacting substances to the simple methylol phenol monomers include *o*-cresol, *p*-cresol, salicylaldehyde, 2,4-dimethyl phenol and 2,6-dimethyl phenol.¹²⁹ Bruze and Zimerson also demonstrated that *o*-cresol is a sensitizer which is present in PFRs.¹³⁰

Patch testing with PTBFR at 10% in petrolatum, which is included in most standard series, should be supplemented with other PFRs to which the patient has likely been exposed given the history, or with the patient's own products, because there is no single screening agent for detecting contact allergies to the numerous available PFRs.^{22,116} Contact allergy to *p*-tert-butylcatechol should be suspected in patients who react to PTBFR on patch testing but have no clinically relevant exposure.^{1,121}

PFRs have been reported to cause ICD, depigmentation, and chemical burns as well.^{116,131,132}

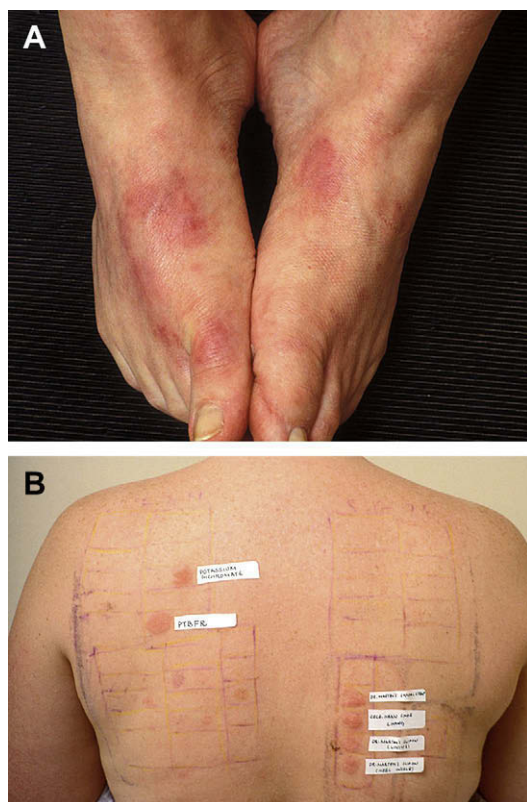


Fig. 5. Shoe dermatitis (A) in a patient with positive patch test reactions to PTBFR, potassium dichromate, and shoe pieces (B).

Phenols and aldehydes (eg, formaldehyde) are skin irritants, and concentrated phenol may cause chemical burns.¹ PTBFR in the adhesive material of bindis has been noted to cause contact depigmentation.^{133,134}

OTHER SELECTED RESINS

Polyester resins are divided into saturated and unsaturated polyesters. Saturated polyesters are made from combining dicarboxylic acids (eg, phthalic acid, maleic acid) primarily in their anhydride forms with polyalcohols (eg, glycerol), and they are often used in the manufacturing of other plastics or water-based paints and coatings.^{1,2} Unsaturated polyesters are produced through esterifications of organic acids or their anhydrides (eg, maleic anhydride, phthalic anhydride, fumaric acid) and diols (eg, diethylene glycol), and they are frequently used in coatings, finishes, varnishes, lacquers, cements, fiberglass mouldings, and glues for industries such as automobile manufacturing, boating, and construction.^{1,2,135}

Box 10

Contact allergens in *p*-*tert*-butylphenol-formaldehyde resins

Monomers

- 5-*tert*-butyl-2-hydroxy-3-hydroxymethyl-benzaldehyde
- 4-*tert*-butyl-2-hydroxymethyl-6-methoxymethyl-phenol
- 2,6-dimethylol *p*-*tert*-butylphenol (2,6-MMPTBP)
- 2-methylol *p*-*tert*-butylphenol (2-MPTBP)

Dimers

- 5,5'-di-*tert*-butyl-2,2'-dihydroxy-3,3'-hydroxymethyl-dibenzyl ether
- 5,5'-di-*tert*-butyl-2,2'-dihydroxy-3-dihydroxymethyl-dibenzyl ether

Linear trimer

- 4-*tert*-butyl-2,6-bis-(5-*tert*-butyl-2-hydroxy-3-hydroxymethyl-benzoyloxymethyl)-phenol
- p*-*tert*-butylcatechol

Data from Refs. ^{1,115,118,120,122–125.}

Box 11

Contact allergens in other phenol-formaldehyde resins

Monomers

- 2-methylol phenol
- 4-methylol phenol
- 3-methylol phenol
- 2,3-dimethylol phenol
- 2,6-dimethylol phenol
- 2,4,6-trimethylol phenol

Dimers

- 4,4-dihydroxy-3-(hydroxymethyl)-diphenyl methane
- 4,4-dihydroxy-3,5-di-(hydroxymethyl)-diphenyl methane
- 4,41-dihydroxy-3,31-di-(hydroxymethyl)-diphenyl methane

o-Cresol

Data from Bruze M. Contact sensitizers in resins based on phenol and formaldehyde. Acta Derm Venereol Suppl (Stockh) 1985;119:1–83; and Bruze M, Zimerson E. Contact allergy to o-cresol—a sensitizer in phenol-formaldehyde resin. Am J Contact Dermat 2002;13(4):198–200.

Despite frequent contact with skin, polyester resins themselves rarely cause ACD and ICD.² When ACD is caused by polyester resins, mostly by unsaturated polyester resins (eg, diethyleneglycol maleate monomer or fumaric acid in the resins) and extremely rarely by saturated polyester resins, involved body areas are mostly the hands and areas associated with airborne exposure (wrists, face, eyelids, neck).^{136–141} This occurs mostly in the occupational setting^{136–140} and occasionally in consumers.¹⁴¹ ICD occurs more frequently than ACD from exposure to polyester resin systems, and may be caused by additives such as styrene, organic peroxides, acetone, and fiberglass fillers, or resin components, including polybasic acids (eg, phthalic anhydride) and polybasic alcohols (eg, propylene glycol).^{2,135,142,143} Chemical burns may also be caused by styrene and organic peroxide additives.¹³⁵ Likewise, ACD occurs more often from additives, auxiliary agents,

and catalysts such as cobalt octoate than from polyester resins themselves.^{2,22,144} Other additives, such as benzoyl peroxide, methyl ethyl ketone peroxide, and cobalt naphthenate appear to be less of a problem today than in the 1950s,^{135,142} although a few case reports of ACD caused by these additives have been made recently.^{145,146} **Table 3** lists recommended patch test concentrations and vehicles for various polyester resin system chemicals.

Amino resins are formed from reactions between an aldehyde and a compound with 1 or more amino groups.¹ These include melamine-formaldehyde and urea-formaldehyde resins, used commonly as laminating and bonding agents in wood and furniture industries; in products such as foam insulations, buttons, and tableware; and to improve wet strength of paper and shrinkage- and crease-resistance of textiles.¹ Finished products containing amino resins generally do not

Table 3**Recommended patch test concentrations and vehicles for polyester resin system chemicals**

Polyester Resin System Chemicals	Patch Test Concentration(s) and Vehicle(s)
Unsaturated polyester resin	10% acet
Activators/accelerators	
Cobalt naphthenate	5% pet
Cobalt octoate	5% pet
Diethylaniline	10% alc
Cross-linking agents	
Methyl methacrylate	2% pet
α -Methylstyrene	1% pet
Styrene (vinyl benzene)	1% olive oil
Vinyl toluene	1% olive oil
Inhibitors	
Hydroquinone	1% pet
Quinone	5% pet
-tert-butylcatechol	1% acet ²² ; 0.25% pet, or 1% pet ³⁸
Organic peroxide catalysts	
Benzoyl peroxide	1% pet
Cumene hydroperoxide	0.5% pet
Cyclohexanone peroxide	0.5% pet
Methyl ethyl ketone peroxide	0.5% pet
Ultraviolet light absorbers	
Benzophenone	5% pet
Benzotriazoles	1% pet

Abbreviations: acet, acetone; pet, petrolatum; alc, alcohol.

Data from Rietschel RL, Fowler JF. *Plastics, adhesives and synthetic resins*. In: Rietschel RL, Fowler JF, editors. *Fisher's contact dermatitis*, 6th edition. Hamilton (ON): BC Decker Inc; 2008. p. 542–65; and de Groot AC, Frosch PJ. *Patch test concentrations and vehicles for testing contact allergens*. In: Frosch PJ, Menné T, Lepoittevin JP, editors. *Contact dermatitis*, 4th edition. Berlin: Springer Verlag; 2006. p. 907–28.

sensitize, but uncured substances may sensitize on occasion.¹ Contact allergy to amino resins can be occupational or nonoccupational and is often combined with formaldehyde allergy, having been reported from textiles, shin pads, facial tissues, fiberboards, foam insulation, composite, orthopedic casts, and gypsum molds.^{147–158} ICD from amino resins is mainly caused by the formaldehyde that can be released.¹ ICD has also been reported in manufacturers of fiberboards with urea-formaldehyde resin.¹⁵⁹ Additionally, airborne skin irritation of the face, ears, and neck has been noted from dust during the production of urea-formaldehyde insulating foam.¹⁶⁰ Even though the amount of formaldehyde released from amino resins has been on the decline (the percentage of high-formaldehyde-releasing textile resins has decreased in the United States from 55% in 1980 to 27% in 1990), ACD or ICD induced by formaldehyde released from amino resins

remains a problem.^{1,147,161,162} Patients should be advised to wash all new clothes before wearing them, because the potential for formaldehyde release from resins decreases with the number of washes with alkaline wash powders.¹⁶³ Patients should also be instructed not to use chlorine bleaches, which increase formaldehyde release.¹⁶³

Polyvinyl resins are produced from the polymerization of vinyl group monomers (eg, vinyl chloride), during which numerous additives, such as antioxidants, stabilizers, initiators, plasticizers, pigments, and flame retardants are used.¹ Polyvinyl chloride (PVC) is the most used plastic after polyethylene, partly because of its low price.¹ The addition of a small amount (<5%) of plasticizer produces a hard PVC, whereas the addition of 30% to 50% plasticizer produces a soft PVC. Soft PVC is used in the production of shoes, cables, gloves, hoses, and films.¹⁶⁴ Because of

Table 4 Recommended patch test concentrations and vehicles for polyvinyl resin system chemicals	
Polyvinyl Resin System Chemicals	Patch Test Concentration and Vehicle
Polyvinyl resins	10% aq
Aldehydes	
Glyoxal (dialdehyde)	1% aq
Antioxidants	
Bisphenol A	1% pet
Biocides	
Benzisothiazolinone	0.1% pet
Pyridine derivatives	N/A
Inhibitors	
Bisphenol A	1% pet
Organic pigments	N/A
Plasticizers	
Dibutyl phthalate	5% pet
Diethyl phthalate	5% pet
Dioctyl phthalate	5% pet
Epoxy resin	1% pet
Stabilizers	
Dibutyl tin dilaurate	0.5% pet
Dibutyl tin maleate	0.5% pet
Diphenylthiourea	1% pet
Epoxy resin	1% pet
Ultraviolet light absorbers	
Benzophenones	5% pet
Resorcinol monobenzoate	1% pet

Abbreviations: aq, aqueous; pet, petrolatum; N/A, not available.
Data from Refs.^{22,38,164–173}

its toughness and rigidity, hard PVC is used in agricultural products, sewage systems, drinking water pipes, furniture, window frames, dishes, and packages.¹ In the final PVC product, there are free monomers and additives which may cause sensitizations and ACD.^{165–174} **Table 4** gives recommended patch test concentrations and vehicles for polyvinyl resin system chemicals which have been reported to induce contact sensitization. ICD has been noted to occur with plasticizers and stabilizers (eg, dibutyl thiomalate, dibutyl sebacate, dioctyl phthalate),^{1,166,175} but it may also be caused by exposure to PVC powder in hot and humid environments.¹⁷⁶ Contact urticaria caused by PVC components (eg, phthalates) has also been reported.^{174,177}

Polystyrene resins are formed from the polymerization of styrene monomers using peroxide as an initiator.¹ Stabilizers (eg, benzophenones, organic nickel) are usually added to improve light stability.¹ Polystyrene resins are used in such products as packaging and insulation material, disposable tableware, electrical appliances, toys, handles, and pipes.¹ Contact allergy to styrene is rare but has been reported.^{178–180} Although styrene has generally been considered a mild irritant,¹ it has occasionally been reported to cause chemical burns.¹³⁵

Other resins, such as polyolefins (eg, polyethylene, polypropylene), polyamides, and polycarbonates, very rarely cause ACD and ICD.¹

SUMMARY

Plastic resin systems have an increasingly diverse array of applications and also induce health hazards, the most common of which are ACD and ICD, and less commonly contact urticaria, pigmentary changes, and photoallergic contact dermatitis. Other health hazards, especially in the occupational setting, include asthma, rhinoconjunctivitis, and paresthesias ([meth]acrylics). These resin systems include epoxies (the most frequent synthetic resin system to cause contact dermatitis), (meth)acrylics, polyurethanes, phenol-formaldehydes, polyesters, amino resins (melamine-formaldehydes, urea-formaldehydes), polyvinyls, polystyrenes, polyolefins, polyamides, and polycarbonates. Contact dermatitis usually occurs as a result of exposure to the monomers and additives in the occupational setting, although reports from consumers using the raw materials or end products periodically surface. Resin- and additive-induced direct contact dermatitis usually presents on the hands, fingers, and forearms, whereas facial, eyelid, and neck involvement may

occur through indirect contact (eg, via the hands), or from airborne exposure.

To prevent irritation, sensitization, or both from resins and additives, workers should be educated and informed of the risks before handling these compounds, and taught no-touch techniques. All workers should minimize skin contact with these chemicals, using such protective measures as working in isolated and well-ventilated areas; regularly cleansing hands and contaminated equipment; and using appropriate chemical protective clothing, especially gloves which fit well, are frequently changed, have low sensitization potentials, and are technically adequate and not easily torn or penetrated. Only thicker PVC gloves, nitrile gloves, or the Silver Shield/4-H gloves (North Safety Products, Cranston, Rhode Island), made of 5 layers of polyethylene-ethylene-vinylalcohol copolymer-polyethylene, provide sufficient protection, because most resins can penetrate thinner PVC, polyethylene, and rubber gloves.^{15,21,135,181–184} However, some investigators have noted that polyethylene gloves do provide protection against methyl methacrylate diffusion.¹ Contaminated skin should be washed thoroughly with soap and water, and contaminated clothing and gloves should be removed immediately. Workers should also protect inflamed or injured skin from resin or additive exposure and should minimize simultaneous exposure to irritants such as organic solvents, because skin irritation increases the risk of sensitization.^{15,181}

REFERENCES

1. Bjorkner B, Ponten A, Zimerson E, et al. Plastic materials. In: Frosch PJ, Menné T, Lepoittevin JP, editors. *Contact dermatitis*. 4th edition. Berlin: Springer Verlag; 2006. p. 583–621.
2. Taylor JS. Occupational dermatoses. In: Alderman MH, Hanley MJ, editors. *Clinical medicine for the occupational physician*. New York: Marcel Dekker, Inc; 1982. p. 299–344.
3. Amado A, Taylor JS. Contact allergy to epoxy resins. *Contact Dermatitis* 2008;58(3):186–7.
4. Kanerva L, Jolanki R, Estlander T, et al. Airborne occupational allergic contact dermatitis from triglycidyl-p-aminophenol and tetraglycidyl-4,4'-methylene dianiline in preimpregnated epoxy products in the aircraft industry. *Dermatology* 2000;201(1):29–33.
5. Burrows D, Fregert S, Campbell H, et al. Contact dermatitis from the epoxy resins tetraglycidyl-4,4'-methylene dianiline and o-diglycidyl phthalate in composite material. *Contact Dermatitis* 1984;11(2):80–2.

6. Ponten A, Zimerson E, Bruze M. Contact allergy to the isomers of diglycidyl ether of bisphenol F. *Acta Derm Venereol* 2004;84(1):12–7.
7. Bray PG. Epoxy resins. *Occup Med* 1999;14(4):743–58.
8. Dickel H, Kuss O, Schmidt A, et al. Occupational relevance of positive standard patch-test results in employed persons with an initial report of an occupational skin disease. *Int Arch Occup Environ Health* 2002;75(6):423–34.
9. Flyvholm MA. Contact allergens in registered chemical products. *Contact Dermatitis* 1991;25(1):49–56.
10. Hughes R, Taylor JS. Surveillance of allergic contact dermatitis: epoxy resin and microscopic immersion oil. *J Am Acad Dermatol* 2002;47(6):965–6.
11. Rietschel RL, Mathias CG, Taylor JS, et al. A preliminary report of the occupation of patients evaluated in patch test clinics. *Am J Contact Dermat* 2001;12(2):72–6.
12. Amado A, Taylor JS. Contact dermatitis in the bowling pro shop. *Dermatitis* 2008;19(6):334–8.
13. Taylor JS, Bergfeld WF, Guin JD. Contact dermatitis to knee patch adhesive in boys' jeans: a nonoccupational cause of epoxy resin sensitivity. *Cleve Clin Q* 1983;50(2):123–7.
14. Fregert S. Epoxy dermatitis from the non-working environment. *Br J Dermatol* 1981;105(Suppl 21):63–4.
15. Jolanki R, Kanerva L, Estlander T, et al. Occupational dermatoses from epoxy resin compounds. *Contact Dermatitis* 1990;23(3):172–83.
16. Jolanki R. Occupational skin diseases from epoxy compounds. Epoxy resin compounds, epoxy acrylates and 2,3-epoxypropyl trimethyl ammonium chloride. *Acta Derm Venereol Suppl (Stockh)* 1991;159:1–80.
17. Romyhr O, Nyfors A, Leira HL, et al. Allergic contact dermatitis caused by epoxy resin systems in industrial painters. *Contact Dermatitis* 2006;55(3):167–72.
18. Angelini G, Rigano L, Foti C, et al. Occupational sensitization to epoxy resin and reactive diluents in marble workers. *Contact Dermatitis* 1996;35(1):11–6.
19. van Putten PB, Coenraads PJ, Nater JP. Hand dermatoses and contact allergic reactions in construction workers exposed to epoxy resins. *Contact Dermatitis* 1984;10(3):146–50.
20. Jolanki R, Tarvainen K, Tatar T, et al. Occupational dermatoses from exposure to epoxy resin compounds in a ski factory. *Contact Dermatitis* 1996;34(6):390–6.
21. Omer SA, al-Tawil NG. Contact sensitivity among workers in a paint factory. *Contact Dermatitis* 1994;30(1):55–7.
22. Rietschel RL, Fowler JF. Plastics, adhesives and synthetic resins. In: Rietschel RL, Fowler JF, editors. *Fisher's contact dermatitis*. 6th edition. Hamilton (ON): BC Decker Inc.; 2008. p. 542–65.
23. Fregert S, Thorgeirsson A. Patch testing with low molecular oligomers of epoxy resins in humans. *Contact Dermatitis* 1977;3(6):301–3.
24. Jolanki R, Estlander T, Kanerva L. Occupational contact dermatitis and contact urticaria caused by epoxy resins. *Acta Derm Venereol Suppl (Stockh)* 1987;134:90–4.
25. Lee HN, Pokorny CD, Law S, et al. Cross-reactivity among epoxy acrylates and bisphenol F epoxy resins in patients with bisphenol A epoxy resin sensitivity. *Am J Contact Dermat* 2002;13(3):108–15.
26. Handley J, Burrows D. Dermatitis from hexavalent chromate in the accelerator of an epoxy sealant (PR1422) used in the aircraft industry. *Contact Dermatitis* 1994;30(4):193–6.
27. Kiec-Swierczynska M. Allergy to epoxy compounds over a decade. *Contact Dermatitis* 1995;32(3):180.
28. Maibach HI, Mathias CT. Allergic contact dermatitis from cycloaliphatic epoxide in jet aviation hydraulic fluid. *Contact Dermatitis* 2001;45(1):56.
29. Kanerva L, Estlander T, Jolanki R. Occupational allergic contact dermatitis caused by 2,4,6-tris-(dimethylaminomethyl)phenol, and review of sensitizing epoxy resin hardeners. *Int J Dermatol* 1996;35(12):852–6.
30. de Groot AC. Occupational contact allergy to alpha-naphthyl glycidyl ether. *Contact Dermatitis* 1994;30(4):253–4.
31. Eedy DJ. Carbon-fibre-induced airborne irritant contact dermatitis. *Contact Dermatitis* 1996;35(6):362–3.
32. Tarvainen K, Jolanki R, Estlander T, et al. Immunologic contact urticaria due to airborne methylhexahydrophthalic anhydride and methyltetrahydrophthalic anhydride. *Contact Dermatitis* 1995;32(4):201–9.
33. Allen H, Kaidbey K. Persistent photosensitivity following occupational exposure to epoxy resin. *Arch Dermatol* 1979;115(11):1307–10.
34. Hannu T, Frilander H, Kauppi P, et al. IgE-mediated occupational asthma from epoxy resin. *Int Arch Allergy Immunol* 2009;148(1):41–4.
35. Huygens S, Goossens A. An update on airborne contact dermatitis. *Contact Dermatitis* 2001;44(1):1–6.
36. Dahlquist I, Fregert S. Allergic contact dermatitis from volatile epoxy hardeners and reactive diluents. *Contact Dermatitis* 1979;5(6):406–7.
37. Lyon CC, Beck MH. Epoxy-by-proxy dermatitis. *Contact Dermatitis* 2000;42(5):306.
38. de Groot AC, Frosch PJ. Patch test concentrations and vehicles for testing contact allergens. In: Frosch PJ, Menné T, Lepoittevin JP, editors. *Contact dermatitis*. 4th edition. Berlin: Springer Verlag; 2006. p. 907–28.

39. Kanerva L, Lauerma A, Estlander T, et al. Occupational allergic contact dermatitis caused by photo-bonded sculptured nails and a review of (meth)acrylates in nail cosmetics. *Am J Contact Dermat* 1996;7(2):109–15.
40. Goon AT, Isaksson M, Zimerson E, et al. Contact allergy to (meth)acrylates in the dental series in southern Sweden: simultaneous positive patch test reaction patterns and possible screening allergens. *Contact Dermatitis* 2006;55(4):219–26.
41. Malten KE, Bende WJ. 2-Hydroxy-ethyl-methacrylate and di- and tetraethylene glycol dimethacrylate: contact sensitizers in a photoprepolymer printing plate procedure. *Contact Dermatitis* 1979;5(4):214–20.
42. Bjorkner B. Contact allergy to 2-hydroxypropyl methacrylate (2-HPMA) in an ultraviolet curable ink. *Acta Derm Venereol* 1984;64(3):264–7.
43. Nethercott JR. Skin problems associated with multifunctional acrylic monomers in ultraviolet curing inks. *Br J Dermatol* 1978;98(5):541–52.
44. Ranchoff RE, Taylor JS. Contact dermatitis to anaerobic sealants. *J Am Acad Dermatol* 1985;13(6):1015–20.
45. de Groot AC. Patch testing: test concentrations and vehicles for 3700 chemicals. 2nd edition. Amsterdam: Elsevier; 1994.
46. Tobler M, Wuthrich B, Freiburghaus AU. Contact dermatitis from acrylate and methacrylate compounds in Lowicryl embedding media for electron microscopy. *Contact Dermatitis* 1990;23(2):96–102.
47. Cavelier C, Jelen G, Herve-Bazin B, et al. Irritation and allergy to acrylates and methacrylates. Part I: common monoacrylates and monomethacrylates. *Ann Dermatol Venereol* 1981;108(6–7):549–56.
48. Parker D, Turk JL. Contact sensitivity to acrylate compounds in guinea pigs. *Contact Dermatitis* 1983;9(1):55–60.
49. Bjorkner B. The sensitizing capacity of multifunctional acrylates in the guinea pig. *Contact Dermatitis* 1984;11(4):236–46.
50. Bjorkner B, Niklasson B, Persson K. The sensitizing potential of di-(meth)acrylates based on bisphenol A or epoxy resin in the guinea pig. *Contact Dermatitis* 1984;10(5):286–304.
51. Bjorkner B. Sensitization capacity of acrylated prepolymers in ultraviolet curing inks tested in the guinea pig. *Acta Derm Venereol* 1981;61(1):7–10.
52. Bjorkner B. Sensitizing potential of urethane (meth)acrylates in the guinea pig. *Contact Dermatitis* 1984;11(2):115–9.
53. Bjorkner B. Sensitization capacity of polyester methacrylate in ultraviolet curing inks tested in the guinea pig. *Acta Derm Venereol* 1982;62(2):153–4.
54. Lindstrom M, Alanko K, Keskinen H, et al. Dentist's occupational asthma, rhinoconjunctivitis, and allergic contact dermatitis from methacrylates. *Allergy* 2002;57(6):543–5.
55. Sanchez-Perez J, Gonzalez-Arriba A, Goiriz R, et al. Occupational allergic contact dermatitis to acrylates and methacrylates. *Contact Dermatitis* 2008;58(4):252–4.
56. Kanerva L, Jolanki R, Estlander T. 10 years of patch testing with the (meth)acrylate series. *Contact Dermatitis* 1997;37(6):255–8.
57. Kanerva L. Cross-reactions of multifunctional methacrylates and acrylates. *Acta Odontol Scand* 2001;59(5):320–9.
58. Rustemeyer T, de Groot J, von Blomberg BM, et al. Cross-reactivity patterns of contact-sensitizing methacrylates. *Toxicol Appl Pharmacol* 1998;148(1):83–90.
59. Mowad CM, Ferringer T. Allergic contact dermatitis from acrylates in artificial nails. *Dermatitis* 2004;15(1):51–3.
60. Lazarov A. Sensitization to acrylates is a common adverse reaction to artificial fingernails. *J Eur Acad Dermatol Venereol* 2007;21(2):169–74.
61. Sadoh DR, Sharief MK, Howard RS. Occupational exposure to methyl methacrylate monomer induces generalised neuropathy in a dental technician. *Br Dent J* 1999;186(8):380–1.
62. Fisher AA, Baran RL. Adverse reactions to acrylate sculptured nail with particular reference to prolonged paresthesia. *Am J Contact Dermat* 1991;2:38–42.
63. Sood A, Taylor JS. Acrylic reactions: a review of 56 cases. *Contact Dermatitis* 2003;48(6):346–7.
64. Rustemeyer T, Frosch PJ. Occupational skin diseases in dental laboratory technicians. (I). Clinical picture and causative factors. *Contact Dermatitis* 1996;34(2):125–33.
65. Aalto-Korte K, Alanko K, Kuuliala O, et al. Occupational methacrylate and acrylate allergy from glues. *Contact Dermatitis* 2008;58(6):340–6.
66. Corazza M, Bacilieri S, Virgili A. Anaerobic sealants: still a problem today. *Eur J Dermatol* 2000;10(6):468–9.
67. Nethercott JR. Allergic contact dermatitis due to an epoxy acrylate. *Br J Dermatol* 1981;104(6):697–703.
68. Nethercott JR, Jakubovic HR, Pilger C, et al. Allergic contact dermatitis due to urethane acrylate in ultraviolet cured inks. *Br J Ind Med* 1983;40(3):241–50.
69. Dutree-Meulenberg RO, Naafs B, van Joost T, et al. Contact dermatitis caused by urethane acrylates in a hearing aid. *Contact Dermatitis* 1991;24(2):143–5.
70. Bjorkner B, Niklasson B. Influence of the vehicle on elicitation of contact allergic reactions to acrylic compounds in the guinea pig. *Contact Dermatitis* 1984;11(5):268–78.

71. Estlander T, Rajaniemi R, Jolanki R. Hand dermatitis in dental technicians. *Contact Dermatitis* 1984;10(4):201–5.
72. Alanko K, Susitaival P, Jolanki R, et al. Occupational skin diseases among dental nurses. *Contact Dermatitis* 2004;50(2):77–82.
73. Estlander T, Keskinen H, Jolanki R, et al. Occupational dermatitis from exposure to polyurethane chemicals. *Contact Dermatitis* 1992;27(3):161–5.
74. Liippo J, Lammintausta K. Contact sensitization to 4,4'-diaminodiphenylmethane and to isocyanates among general dermatology patients. *Contact Dermatitis* 2008;59(2):109–14.
75. Bello D, Herrick CA, Smith TJ, et al. Skin exposure to isocyanates: reasons for concern. *Environ Health Perspect* 2007;115(3):328–35.
76. Baur X, Marek W, Ammon J, et al. Respiratory and other hazards of isocyanates. *Int Arch Occup Environ Health* 1994;66(3):141–52.
77. Littorin M, Truedsson L, Welinder H, et al. Acute respiratory disorder, rhinoconjunctivitis and fever associated with the pyrolysis of polyurethane derived from diphenylmethane diisocyanate. *Scand J Work Environ Health* 1994;20(3):216–22.
78. Larsen TH, Gregersen P, Jemec GB. Skin irritation and exposure to diisocyanates in orthopedic nurses working with soft casts. *Am J Contact Dermat* 2001;12(4):211–4.
79. Daftarian HS, Lushniak BD, Reh CM, et al. Evaluation of self-reported skin problems among workers exposed to toluene diisocyanate (TDI) at a foam manufacturing facility. *J Occup Environ Med* 2002;44(12):1197–202.
80. Duprat P, Gradiski D, Marignac B. The irritant and allergenic action of two isocyanates: toluene diisocyanate (TDI) and diphenylmethane diisocyanate (MDI). *Eur J Toxicol Environ Hyg* 1976;9(1):43–53.
81. White IR, Stewart JR, Rycroft RJ. Allergic contact dermatitis from an organic di-isocyanate. *Contact Dermatitis* 1983;9(4):300–3.
82. Thorne PS, Hillebrand JA, Lewis GR, et al. Contact sensitivity by diisocyanates: potencies and cross-reactivities. *Toxicol Appl Pharmacol* 1987;87(1):155–65.
83. Tanaka K, Takeoka A, Nishimura F, et al. Contact sensitivity induced in mice by methylene bisphenyl diisocyanate. *Contact Dermatitis* 1987;17(4):199–204.
84. Yasuda K, Nozawa G, Goto T, et al. Experimental studies on TDI dermatitis in mice. *J Toxicol Sci* 1980;5(1):11–21.
85. Militello G, Sasseville D, Ditre C, et al. Allergic contact dermatitis from isocyanates among sculptors. *Dermatitis* 2004;15(3):150–3.
86. Frick M, Isaksson M, Bjorkner B, et al. Occupational allergic contact dermatitis in a company manufacturing boards coated with isocyanate lacquer. *Contact Dermatitis* 2003;48(5):255–60.
87. Kerre S. Allergic contact dermatitis to MDI in an office application. *Contact Dermatitis* 2008;58(5):313–4.
88. Frick M, Bjorkner B, Hamnerius N, et al. Allergic contact dermatitis from dicyclohexylmethane-4,4'-diisocyanate. *Contact Dermatitis* 2003;48(6):305–9.
89. Hannu T, Estlander T, Jolanki R. Allergic contact dermatitis due to MDI and MDA from accidental occupational exposure. *Contact Dermatitis* 2005;52(2):108–9.
90. Goossens A, Detienne T, Bruze M. Occupational allergic contact dermatitis caused by isocyanates. *Contact Dermatitis* 2002;47(5):304–8.
91. Belsito DV. Common shoe allergens undetected by commercial patch-testing kits: dithiodimorpholine and isocyanates. *Am J Contact Dermat* 2003;14(2):95–6.
92. Morgan CJ, Haworth AE. Allergic contact dermatitis from 1,6-hexamethylene diisocyanate in a domestic setting. *Contact Dermatitis* 2003;48(4):224.
93. Alomar A. Contact dermatitis from a fashion watch. *Contact Dermatitis* 1986;15:44–5.
94. Vilaplana J, Romaguera C, Grimalt F. Allergic contact dermatitis from aliphatic isocyanate on spectacle frames. *Contact Dermatitis* 1987;16(2):113.
95. Fregert S. Allergic contact reaction to diphenyl-4,4'-diisocyanate. *Contact Dermatitis Newsletter* 1967;2:17.
96. Rothe A. Zur Frage arbeitsbedingter Hautschädigungen durch Polyurethanchemikalien [Occupational dermatoses due to polyurethane drugs]. *Berufsdermatosen* 1976;24:7–24 [in German].
97. Tait CP, Delaney TA. Reactions causing reactions: allergic contact dermatitis to an isocyanate metabolite but not to the parent compound. *Australas J Dermatol* 1999;40(2):116–7.
98. Fortina AB, Piaserico S, Larese F, et al. Diaminodiphenylmethane (DDM): frequency of sensitization, clinical relevance and concomitant positive reactions. *Contact Dermatitis* 2001;44(5):283–8.
99. Kanerva L, Estlander T, Jolanki R, et al. Occupational urticaria from welding polyurethane. *J Am Acad Dermatol* 1991;24(5 Pt 2):825–6.
100. Valks R, Conde-Salazar L, Barrantes OL. Occupational allergic contact urticaria and asthma from diphenylmethane-4,4'-diisocyanate. *Contact Dermatitis* 2003;49(3):166–7.
101. Bello D, Sparer J, Redlich CA, et al. Slow curing of aliphatic polyisocyanate paints in automotive refinishing: a potential source for skin exposure. *J Occup Environ Hyg* 2007;4(6):406–11.
102. Boutin M, Dufresne A, Ostiguy C, et al. Determination of airborne isocyanates generated during the thermal degradation of car paint in body repair shops. *Ann Occup Hyg* 2006;50(4):385–93.

103. Littorin M, Welinder H, Skarping G, et al. Exposure and nasal inflammation in workers heating polyurethane. *Int Arch Occup Environ Health* 2002;75(7):468–74.
104. Frick-Engfeldt M, Isaksson M, Zimerson E, et al. How to optimize patch testing with diphenylmethane diisocyanate. *Contact Dermatitis* 2007;57(3):138–51.
105. Aalto-Korte K, Alanko K, Kuuliala O, et al. Late reactions in patch tests: a 4-year review from a clinic of occupational dermatology. *Contact Dermatitis* 2007;56(2):81–6.
106. Frick M, Zimerson E, Karlsson D, et al. Poor correlation between stated and found concentrations of diphenylmethane-4,4'-diisocyanate (4,4'-MDI) in petrolatum patch-test preparations. *Contact Dermatitis* 2004;51(2):73–8.
107. Nagashima C, Tomitaka-Yagami A, Matsunaga K. Contact dermatitis due to para-tertiary-butylphenol-formaldehyde resin in a wetsuit. *Contact Dermatitis* 2003;49(5):267–8.
108. Bruze M. Contact sensitizers in resins based on phenol and formaldehyde. *Acta Derm Venereol Suppl (Stockh)* 1985;119:1–83.
109. Massone L, Anonide A, Borghi S, et al. Sensitization to para-tertiary-butylphenol-formaldehyde resin. *Int J Dermatol* 1996;35(3):177–80.
110. Oztas P, Polat M, Cinar L, et al. Shoe dermatitis from para-tertiary butylphenol formaldehyde. *Contact Dermatitis* 2007;56(5):294–5.
111. Tarvainen K. Analysis of patients with allergic patch test reactions to a plastics and glues series. *Contact Dermatitis* 1995;32(6):346–51.
112. Dahlquist I. Contact allergy to parateritary butylphenol formaldehyde resin in an adhesive label. *Contact Dermatitis* 1984;10(1):54.
113. Shono M, Ezoe K, Kaniwa MA, et al. Allergic contact dermatitis from para-tertiary-butylphenol-formaldehyde resin (PTBP-FR) in athletic tape and leather adhesive. *Contact Dermatitis* 1991;24(4):281–8.
114. Avenel-Audran M, Goossens A, Zimerson E, et al. Contact dermatitis from electrocardiograph-monitoring electrodes: role of p-tert-butylphenol-formaldehyde resin. *Contact Dermatitis* 2003;48(2):108–11.
115. Barros MA, Baptista A, Correia TM, et al. Patch testing in children: a study of 562 schoolchildren. *Contact Dermatitis* 1991;25(3):156–9.
116. Bruze M, Fregert S, Zimerson E. Contact allergy to phenol-formaldehyde resins. *Contact Dermatitis* 1985;12(2):81–6.
117. Fousereau J, Cavelier C, Selig D. Occupational eczema from para-tertiary-butylphenol formaldehyde resins: a review of the sensitizing resins. *Contact Dermatitis* 1976;2(5):254–8.
118. Hayakawa R, Ogino Y, Suzuki M, et al. Allergic contact dermatitis from para-tertiary-butylphenol-formaldehyde resin (PTBP-F-R). *Contact Dermatitis* 1994;30(3):187–8.
119. Zimerson E, Bruze M. Contact allergy to the monomers in p-tert-butylphenol-formaldehyde resin. *Contact Dermatitis* 2002;47(3):147–53.
120. Zimerson E, Bruze M. Contact allergy to the monomers of p-tert-butylphenol-formaldehyde resin in the guinea pig. *Contact Dermatitis* 1998;39(5):222–6.
121. Zimerson E, Bruze M, Goossens A. Simultaneous p-tert-butylphenol-formaldehyde resin and p-tert-butylcatechol contact allergies in man and sensitizing capacities of p-tert-butylphenol and p-tert-butylcatechol in guinea pigs. *Occup Environ Med* 1999;41(1):23–8.
122. Zimerson E, Bruze M. Demonstration of the contact sensitizer p-tert-butylcatechol in p-tert-butylphenol formaldehyde resin. *Am J Contact Dermat* 1999;10(1):2–6.
123. Zimerson E, Bruze M. Sensitizing capacity of some trimers in p-tert-butylphenol-formaldehyde resin. *Contact Dermatitis* 2002;47(1):40–6.
124. Zimerson E, Bruze M. Contact allergy to 5,5'-di-tert-butyl-2,2'-dihydroxy-(hydroxymethyl)-dibenzyl ethers, sensitizers, in p-tert-butylphenol-formaldehyde resin. *Contact Dermatitis* 2000;43(1):20–6.
125. Zimerson E, Bruze M. Low-molecular-weight contact allergens in p-tert-butylphenol-formaldehyde resin. *Am J Contact Dermat* 2002;13(4):190–7.
126. Zimerson E, Bruze M. Sensitizing capacity of two monomeric aldehyde components in p-tert-butylphenol-formaldehyde resin. *Acta Derm Venereol* 2002;82(6):418–22.
127. Owen CM, Beck MH. Occupational allergic contact dermatitis from phenol-formaldehyde resins. *Contact Dermatitis* 2001;45(5):294–5.
128. Rademaker M. Contact dermatitis to phenol-formaldehyde resin in two plywood factory workers. *Australas J Dermatol* 2002;43(3):224–5.
129. Bruze M, Zimerson E. Cross-reaction patterns in patients with contact allergy to simple methylol phenols. *Contact Dermatitis* 1997;37(2):82–6.
130. Bruze M, Zimerson E. Contact allergy to o-cresol—a sensitizer in phenol-formaldehyde resin. *Am J Contact Dermat* 2002;13(4):198–200.
131. Fregert S. Irritant dermatitis from phenol-formaldehyde resin powder. *Contact Dermatitis* 1980;6(7):493.
132. Bruze M, Almgren G. Occupational dermatoses in workers exposed to resins based on phenol and formaldehyde. *Contact Dermatitis* 1988;19(4):272–7.
133. Mathur AK, Srivastava AK, Singh A, et al. Contact depigmentation by adhesive material of bindi. *Contact Dermatitis* 1991;24(4):310–1.
134. Bajaj AK, Gupta SC, Chatterjee AK. Contact depigmentation from free para-tertiary-butylphenol in bindi adhesive. *Contact Dermatitis* 1990;22(2):99–102.

135. Bourne LB, Milner FJ. Polyester resin hazards. *Br J Ind Med* 1963;20:100–9.
136. Tarvainen K, Jolanki R, Estlander T. Occupational contact allergy to unsaturated polyester resin cements. *Contact Dermatitis* 1993;28(4):220–4.
137. Kanerva L, Estlander T, Alanko K, et al. Occupational allergic contact dermatitis from unsaturated polyester resin in a car repair putty. *Int J Dermatol* 1999;38(6):447–52.
138. Pfaffli P, Jolanki R, Estlander T, et al. Identification of sensitizing diethyleneglycol maleate in a two-component polyester cement. *Contact Dermatitis* 2002;46(3):170–3.
139. Minamoto K, Nagano M, Yonemitsu K, et al. Allergic contact dermatitis from unsaturated polyester resin consisting of maleic anhydride, phthalic anhydride, ethylene glycol and dicyclopentadiene. *Contact Dermatitis* 2002;46(1):62–3.
140. Liden C, Lofstrom A, Storgards-Hatam K. Contact allergy to unsaturated polyester in a boatbuilder. *Contact Dermatitis* 1984;11(4):262–4.
141. MacFarlane AW, Curley RK, King CM. Contact sensitivity to unsaturated polyester resin in a limb prosthesis. *Contact Dermatitis* 1986;15(5):301–3.
142. Malten KE. Recently reported causes of contact dermatitis due to synthetic resins and hardeners. *Contact Dermatitis* 1979;5(1):11–23.
143. Lim J, Balzer JL, Wolf CR, et al. Fiber glass reinforced plastics. Associated occupational health problems. *Arch Environ Health* 1970;20(4):540–4.
144. Anavekar NS, Nixon R. Occupational allergic contact dermatitis to cobalt octoate included as an accelerator in a polyester resin. *Australas J Dermatol* 2006;47(2):143–4.
145. Bhushan M, Craven NM, Beck MH. Contact allergy to methyl ethyl ketone peroxide and cobalt in the manufacture of fibreglass-reinforced plastics. *Contact Dermatitis* 1998;39(4):203.
146. Minamoto K, Nagano M, Inaoka T, et al. Allergic contact dermatitis due to methyl ethyl ketone peroxide, cobalt naphthenate and acrylates in the manufacture of fibreglass-reinforced plastics. *Contact Dermatitis* 2002;46(1):58–9.
147. Hatch KL, Maibach HI. Textile dermatitis: an update (I). Resins, additives and fibers. *Contact Dermatitis* 1995;32(6):319–26.
148. Fowler JF, Skinner SM, Belsito DV. Allergic contact dermatitis from formaldehyde resins in permanent press clothing: an underdiagnosed cause of generalized dermatitis. *J Am Acad Dermatol* 1992;27(6 Pt 1):962–8.
149. Aalto-Korte K, Jolanki R, Estlander T. Formaldehyde-negative allergic contact dermatitis from melamine-formaldehyde resin. *Contact Dermatitis* 2003;49(4):194–6.
150. Lazarov A. Textile dermatitis in patients with contact sensitization in Israel: a 4-year prospective study. *J Eur Acad Dermatol Venerol* 2004;18(5):531–7.
151. Sommers S, Wilkinson SM, Dodman B. Contact dermatitis due to urea-formaldehyde resin in shin-pads. *Contact Dermatitis* 1999;40(3):159–60.
152. Peck SM, Palitz LL. Sensitization to facial tissues with urea-formaldehyde resin (wet-strength). *J Am Med Assoc* 1956;160(14):1226–7.
153. Finch M, Prais L, Foulds I. Allergic contact dermatitis from medium-density fibreboard containing melamine formaldehyde resin. *Contact Dermatitis* 1999;41(5):291.
154. Bell HK, King CM. Allergic contact dermatitis from urea-formaldehyde resin in medium-density fibreboard (MDF). *Contact Dermatitis* 2002;46(4):247.
155. L'Abbe KA, Hoey JR. Review of the health effects of urea-formaldehyde foam insulation. *Environ Res* 1984;35(1):246–63.
156. Isaksson M, Zimerson E, Bruze M. Occupational dermatoses in composite production. *J Occup Environ Med* 1999;41(4):261–6.
157. Ross JS, Rycroft JG, Bronin E. Melamine-formaldehyde contact dermatitis in orthopaedic practice. *Contact Dermatitis* 1992;26(3):203–4.
158. Fregert S. Formaldehyde dermatitis from a gypsum-melamine resin mixture. *Contact Dermatitis* 1981;7(1):56.
159. Vale PT, Rycroft RJ. Occupational irritant contact dermatitis from fibreboard containing urea-formaldehyde resin. *Contact Dermatitis* 1988;19(1):62.
160. Dooms-Goossens AE, Debusschere KM, Gevers DM, et al. Contact dermatitis caused by airborne agents. A review and case reports. *J Am Acad Dermatol* 1986;15(1):1–10.
161. Berrens L, Young E, Jansen LH. Free formaldehyde in textiles in relation to formalin contact sensitivity. *Br J Dermatol* 1964;76:110–5.
162. Scheman AJ, Carroll PA, Brown KH, et al. Formaldehyde-related textile allergy: an update. *Contact Dermatitis* 1998;38(6):332–6.
163. Cockayne SE, McDonagh AJ, Gaskrodger DJ. Occupational allergic contact dermatitis from formaldehyde resin in clothing. *Contact Dermatitis* 2001;44(2):109–10.
164. Park SG, Lee EC, Hong WK, et al. A case of occupational allergic contact dermatitis due to PVC hose. *J Occup Health* 2008;50(2):197–200.
165. Vidovic R, Kanský A. Contact dermatitis in workers processing polyvinyl chloride plastics. *Derm Beruf Umwelt* 1985;33(3):104–5.
166. Schulsinger C, Mollgaard K. Polyvinyl chloride dermatitis not caused by phthalates. *Contact Dermatitis* 1980;6(7):477–80.

167. Tung RC, Taylor JS. Contact dermatitis from polyvinyl chloride identification bands. *Am J Contact Dermat* 1998;9(4):234–6.
168. Fregert S, Rorsman H. Hypersensitivity to epoxy resins used as plasticizers and stabilizers in polyvinyl chloride (PVC) resins. *Acta Derm Venereol* 1963;43:10–3.
169. Aalto-Korte K, Alanko K, Henriks-Eckerman ML, et al. Allergic contact dermatitis from bisphenol A in PVC gloves. *Contact Dermatitis* 2003;49(4):202–5.
170. Kanerva L, Jolanki R, Estlander T. Organic pigment as a cause of plastic glove dermatitis. *Contact Dermatitis* 1985;13(1):41–3.
171. Fregert S, Trulsson L, Zimerson E. Contact allergic reactions to diphenylthiourea and phenylisothiocyanate in PVC adhesive tape. *Contact Dermatitis* 1982;8(1):38–42.
172. Huh WK, Masuji Y, Tada J, et al. Allergic contact dermatitis from a pyridine derivative in polyvinyl chloride leather. *Am J Contact Dermat* 2001;12(1):35–7.
173. Aalto-Korte K, Alanko K, Henriks-Eckerman ML, et al. Antimicrobial allergy from polyvinyl chloride gloves. *Arch Dermatol* 2006;142(10):1326–30.
174. Estlander T, Jolanki R, Kanerva L. Dermatitis and urticaria from rubber and plastic gloves. *Contact Dermatitis* 1986;14(1):20–5.
175. Di Lernia V, Cameli N, Patrizi A. Irritant contact dermatitis in a child caused by the plastic tube of an infusion system. *Contact Dermatitis* 1989;21(5):339–40.
176. Goh CL, Ho SF. An outbreak of acneiform eruption in a polyvinyl chloride manufacturing factory. *Derm Beruf Umwelt* 1988;36(2):53–7.
177. Sugiura K, Sugiura M, Hayakawa R, et al. A case of contact urticaria syndrome due to di(2-ethylhexyl) phthalate (DOP) in work clothes. *Contact Dermatitis* 2002;46(1):13–6.
178. Conde-Salazar L, Gonzalez MA, Guimaraens D, et al. Occupational allergic contact dermatitis from styrene. *Contact Dermatitis* 1989;21(2):112.
179. Edwards EK Jr, Edwards EK Sr. Unusual cutaneous reaction to polystyrene in an otherwise healthy population. *Contact Dermatitis* 1998;38(1):50.
180. Sjoborg S, Fregert S, Trulsson L. Contact allergy to styrene and related chemicals. *Contact Dermatitis* 1984;10(2):94–6.
181. Uter W, Ruhl R, Pfahlberg A, et al. Contact allergy in construction workers: results of a multifactorial analysis. *Ann Occup Hyg* 2004;48(1):21–7.
182. Pegum JS. Penetration of protective gloves by epoxy resin. *Contact Dermatitis* 1979;5(5):281–3.
183. Blanken R, Nater JP, Veenhoff E. Protection against epoxy resins with glove materials. *Contact Dermatitis* 1987;16(1):46–7.
184. Lachapelle JM. Preventive measures in allergic contact dermatitis. In: Dyall-Smith D, Marks R, editors. *Dermatology at the millennium: the proceedings of the 19th World Congress of Dermatology*. London: Informa Health Care; 1999. p. 234–8.