

A new application for epoxy resins resulting in occupational allergic contact dermatitis: the three-dimensional printing industry

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Epoxy resin systems (ERSs) are strong sensitizers that are responsible for occupational dermatitis in many applications, such as in the aircraft industry (1), including helicopter assembly (2), and wind turbine rotor manufacture (3). Since the 1990s (4), ERSs have also been introduced in three-dimensional (3D) printing, which has become a

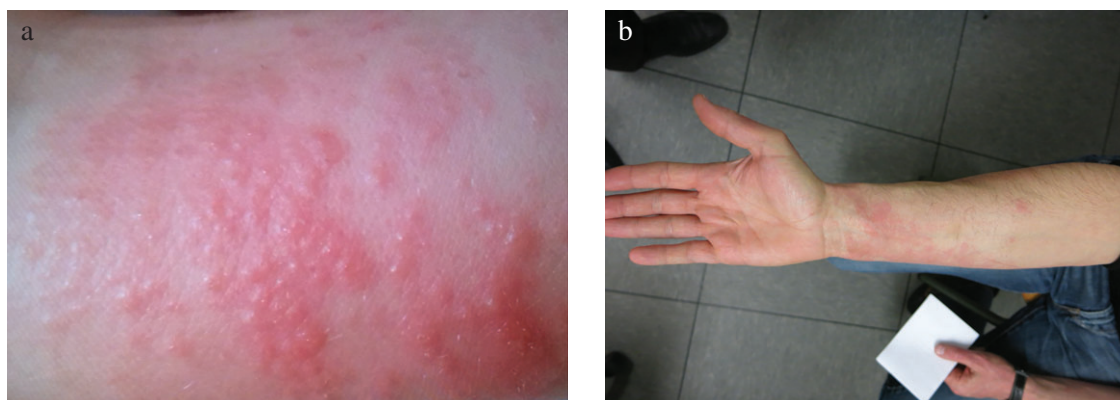


Fig. 1. (a) Erythematous papules on the right wrist in case 1. (b) Erythematous plaques on the forearm and wrist in case 2.

new source of epoxy resin sensitization. Here, we present 2 such patients who presented with severe allergic contact dermatitis caused by ERSs.

Case Reports

Two patients working in the same 3D printing company were referred to our department by their occupational physician in February 2015. Both were involved in cleaning liquid resin prints with isopropanol, while wearing nitrile gloves and sleeve covers only. The first patient was a 34-year-old female. She started to develop erythematous non-follicular papules, pustules, and vesicles, initially on the wrist, hands, and forearms, and then spreading to the face, neck, ears, legs and abdomen 2 weeks after she commenced her job in December 2014 (Fig. 1a). The second patient, a 44-year-old man, developed erythematous itchy lesions on the backs of the hands, spreading to the forearms, axillae and abdomen (Fig. 1b) in November 2014, 4 weeks after he started his job at the same worksite.

Patch tests were performed with the baseline, plastic/glue, acrylate and epoxy resin series, by the use of IQ Ultra[®] test chambers (Chemotechnique Diagnostics, Vellinge, Sweden) covered with Mefix[®] tape (Mölnlycke Healthcare, Göteborg, Sweden). In the first case, semi-open tests with the resins, which the patient sometimes came into direct contact with, tested 'as is', were also performed, with readings being performed on Day 2 and Day 6 according to ESCD guidelines (5); positive patch test reactions are shown in Table 1. Ten days after the patch testing, the first patient developed urticarial and erythema multiforme-like lesions on the trunk, arm, and legs (Fig. 2), the biopsy of which showed a dermal perivascular and interstitial mixed inflammatory infiltrate with eosinophils.

Table 1. Patch test results after 2 and 6 days. All test preparations in pet

	Patient 1		Patient 2	
	D2	D6	D2	D6
Resins				
Epoxy resin bisphenol A 1%	–	+	+	+
Epoxy resin bisphenol F 0.25%	–	–	+	+
Resins 'as is', semi-open	–	++	NT	NT
Aromatic urethane diacrylate 0.05%	+	+	–	–
Diluents				
Triglycidyl- <i>p</i> -aminophenol 0.5%	++	++	+	+
2-Phenyl glycidyl ether 0.25%	–	–	+	+
1,6-Hexanediol diglycidyl ether 0.25%	–	–	+	++
1,4-Butanediol diglycidyl ether 0.25%	–	–	+	++
Hardener				
4,4'-Diaminodiphenyl-methane 0.5%	–	–	–	+

NT, not tested.

Discussion

Three-dimensional printing enables the production of complex objects based on 3D computer-aided design data. Plastics are the materials most often used in 3D printing, and ERSs have been introduced in order to provide a combination of great strength, stiffness, and lightness.

To our knowledge, these are the first case reports of severe occupational allergic contact dermatitis – with airborne and systemic features – caused by epoxy resin compounds used in 3D printing. The first patient had positive reactions to different resins provided by the company



Fig. 2. Urticarial and erythema multiforme-like flare-up 10 days after patch testing in case 1 (without occupational contact).

(tested 'as is' semi-open; Fig. 3), to bisphenol A diglycidyl ether (BADGE) resin as present in the baseline series, to a diluent, namely, triglycidyl-*p*-aminophenol 0.5% pet., which is a known allergen in the aircraft industry (2) (kindly provided by the department of occupational and environmental dermatology, Malmö, Sweden), and also to an aromatic urethane diacrylate. The second patient had positive reactions to BADGE, to bisphenol F diglycidyl ether, to different diluents, that is, phenyl glycidyl ether, hexanediol diglycidyl ether, butanediol diglycidyl ether, and triglycidyl-*p*-aminophenol 0.5% pet., and also to a hardener, diaminodiphenyl methane.

Unfortunately, material data safety sheets could be obtained for only some of the resins that the patients came into contact with. Moreover, they did not specify all the ingredients. According to them, 'Cycloaliphatic epoxy resins, epoxy resins, diacrylate esters, acrylate esters, and aliphatic trifunctional epoxy resins' were present, some with confidential concentrations. Also, no CAS numbers were mentioned for the acrylate and diacrylate esters. Therefore, we could not identify the specific allergens in these resins.

These cases show that, in order to detect the sensitizing culprits in 3D printing, patch testing needs to be



Fig. 3. Semi-open tests with several resins 'as is' in case 1 (day 6).

performed with acrylate and epoxy resins, diluents, and hardeners. Ideally, the resins that the patients have actually come into contact with should also be tested, and, if direct skin contact has occurred, a semi-open test with the resin 'as is' can be considered (5).

In view of the extremely short sensitization periods, the use of less sensitizing epoxy resin monomers (6) and better protective measures in 3D printing are required.

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