

Schubert Steffen (Orcid ID: 0000-0002-2359-2518)
Bauer Andrea (Orcid ID: 0000-0002-4411-3088)
Geier Johannes (Orcid ID: 0000-0002-5047-8948)
Brans Richard (Orcid ID: 0000-0002-1245-024X)

Occupational contact dermatitis in painters and varnishers: data from the Information Network of Departments of Dermatology (IVDK), 2000 to 2019

Steffen Schubert¹, Andrea Bauer², Uwe Hillen³, Thomas Werfel⁴, Johannes Geier¹, Richard Brans^{5,6};
for the IVDK

1 Information Network of departments of Dermatology, Institute at the University Medical Centre
Göttingen, Göttingen, Germany

2 Department of Dermatology, University Allergy Center, University Hospital Carl Gustav Carus,
Technical University Dresden, Dresden, Germany

3 Vivantes Klinikum Neukölln, Clinic for Dermatology und Venerology, Berlin, Germany

4 Department of Dermatology and Allergy, Division of Immunodermatology and Allergy Research,
Hannover Medical School, Hannover, Germany

5 Institute for Interdisciplinary Dermatologic Prevention and Rehabilitation (iDerm) at the University
of Osnabrück, Osnabrück, Germany

6 Department of Dermatology, Environmental Medicine and Health Theory, University of Osnabrück,
Osnabrück, Germany

Conflict of interest: The authors have no conflicts of interest to declare.

Correspondence:

Dr. rer. nat. Steffen Schubert
Information Network of Departments of Dermatology - IVDK
Institute at the University Medical Center Göttingen
Geiststraße 3, 37073 Göttingen, Germany
Tel: 0049-551 - 50539622
Fax: 0049-551 – 50539629
Email: sschube4@gwdg.de

Keywords

allergic contact dermatitis, painter, varnisher, methylisothiazolinone, epoxy resin, face dermatitis,
occupational dermatitis, patch test, methylchloroisothiazolinone

This article has been accepted for publication and undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process which may lead to differences between this version and the [Version of Record](#). Please cite this article as doi: [10.1111/cod.13935](https://doi.org/10.1111/cod.13935)

Abstract

Introduction

Painters and varnishers ("painters") are exposed to various contact allergens and skin irritants, and therefore, at risk to develop occupational dermatitis (OD).

Objective

To describe the spectrum of occupational sensitizations in painters and revise corresponding current patch test recommendations.

Patients and Methods

Retrospective analysis of Information Network of Departments of Dermatology (IVDK) data from 2000 to 2019 with focus on male painters with OD, aged 20-59 years (n=557) in comparison to age-matched male painters without OD (n=422) and male OD patients that have had never worked as painters (n=13862).

Results

Male painters with OD have a significantly higher rate of allergic contact dermatitis and face dermatitis than male patients with OD working in other professions. Positive patch tests to epoxy resin, methylisothiazolinone (MI), and methylchloroisothiazolinone (MCI)/MI were significantly more frequent in painters with OD than in the other groups. Epoxy resin sensitization was significantly associated with face dermatitis.

Conclusions

Epoxy resin, MI and MCI/MI represent most important occupational sensitizers in painters. In addition to baseline, resins and glues, and industrial biocides series, patients' own workplace materials should be tested in painters with suspected OD.

1. Introduction

Painters and varnishers (hereinafter referred to as painters) are exposed to a variety of contact allergens and skin irritants in paints and varnishes, adhesives, (wood) preservatives, solvents and detergents, fillers (putty), or (rubber) gloves.^{1, 2} Therefore, they are at risk to develop occupational dermatitis (OD) with a high share of allergic contact dermatitis of the face.³⁻⁵ Paints and varnishes consist of manifold compounds, including colorants (pigments and dyes), binders, solvents, and multiple additives, such as thickeners, softeners, and biocides.¹ Their composition varies according to the field of application (e.g. rust protection in engineering, building trade, automotive industry or wood protection). Important occupational allergens for painters are biocides, mainly isothiazolinones⁶⁻⁸ and formaldehyde,⁹ as well as epoxy compounds,¹⁰⁻¹² isocyanates and other resins.^{1, 2} However, large scale epidemiological data on occupational contact allergy in painters is scarce.¹³ Case report series identified methylisothiazolinone (MI)^{14, 15} and components of epoxy resin systems¹⁰ as occupationally relevant sensitizers causing airborne / face dermatitis. Generally, it is recommended to patch test painters with (suspected) OD with the baseline series and additional tests series selected based on individual exposures, such as those for resins and glues or industrial biocides.^{1, 2, 16}

The objectives of our retrospective analysis were i) to describe the spectrum of occupational contact sensitizations in painters with OD according to data from the Information Network of Departments of Dermatology (IVDK) and ii) based on this, to revise current patch test (PT) recommendations for painters.^{1, 16} As some allergens may also play a role as sensitizers in everyday life, we defined control groups in order to identify allergens specifically occupationally relevant for painters in the baseline series. A special interest was put on painters with OD suffering from face dermatitis.

2. Patients and Methods

The IVDK consists of currently 58 dermatological departments in Germany, Switzerland, and Austria, dedicated to the clinical epidemiology of contact allergy. Its structure and routine operating procedures are described in detail elsewhere.¹⁷ Briefly, patients' histories, clinical data, and PT results are recorded in local databases in the participating centres and, after pseudonymization, transmitted to the IVDK central office at the University Medical Centre of Göttingen, Germany. Data are subjected to standardized quality control, added to the central IVDK database, and analysed according to international standards.^{18, 19}

All IVDK members are also members of the German Contact Dermatitis Research Group (DKG). PTs were performed according to DKG guidelines.^{20, 21} For the present data analysis, PT reactions at day (D)3 were considered. In a few exceptional cases, when a PT reading was performed at D4 instead of D3, this reading was selected. Readings coded as +, ++ or +++, i.e. positive reactions with erythema, infiltration, papules and/or (coalescing) vesicles were rated as positive. PT preparations were purchased from Almirall Hermal, Reinbek, Germany (until 2013), SmartPractice Europe (SmP), Greven, Germany (from 2014 on), and in exceptional cases from Chemotechnique, Vellinge, Sweden. PT exposure time was 24 h in 26.2%, and 48 h in 73.8% of the patients. In 80.6% and 13.0% of the PTs, Finn-Chambers (8 mm inner diameter, SmP) on Scanpor or Hayes test chambers (HAL Allergie GmbH, Düsseldorf, Germany) were used, respectively.

From 2000 to 2019, a total of 212646 patients were patch tested in the departments of dermatology joining the IVDK. Of these, 1361 (737, 54.2% with OD) had been working as painters at the time of patch testing. This patient population was characterized by a distinct sex and age distribution: 979 (71.9%) were males, and 1165 (86.6%) were between 20 and 59 years old. This has a considerable impact on the frequency of sensitization to ubiquitous contact allergens. In order to largely eliminate these confounders, we focused on male painters with OD aged 20-59 years as study group (n=557), and formed two matched control groups: (i) men aged 20-59 years with OD who had never worked as painter (CG1, n=13862), and (ii) male painters aged 20-59 years without OD (CG2, n=422) (figure S1 in the online supplement). Data of female painters with OD aged 20-59 years (n = 81) and of male painters with OD suffering from face dermatitis (n = 76) were analysed separately.

Percentages of proportions of anamnestic items or reaction frequencies in disjunct groups of patients are presented together with exact 95% confidence intervals (CIs). Statistical significance of differences on a 5%-level was concluded from non-overlapping 95%-CIs. Multivariate logistic regression analyses were performed in mutual control for 3 dichotomized explanatory variables, namely positive PT reactions to epoxy resin, MI, and MCI/MI, and the diagnosis of face dermatitis as

target variable. Data was managed and analysed using the statistical analysis software SAS®, version 9.4 (SAS Institute, Cary, NC, USA).

3. Results

3.1 Patient characteristics.

Population characteristics of the study group and the two control groups are shown in table 1. Remarkably, painters with OD (study group) had a significantly lower proportion of hand dermatitis than non-painters with OD (control group 1) (65.4% vs. 79.5%), but more than two and a half times as many patients with face dermatitis (13.2% vs. 5.2%). Instead, the proportion of hand dermatitis patients in the study group was significantly higher than among painters without OD (control group 2) (65.4% vs. 35.1%), while the share of face dermatitis patients in these two groups was almost identical (13.6% vs. 13.5%). Of all three patient groups, the study group had the highest proportion of patients with allergic contact dermatitis (42.5% vs. 32.1% and 17.1%, respectively). Expectedly, paints and varnishes were by far the most frequent suspected allergen sources in the study group (68.8%), followed by other specific occupational materials. Noteworthy, also in 40.0% of control group 2 (painters without OD), paints and varnishes were suspected allergen sources. However, leave-on cosmetics were significantly more often the suspected source in this patient group than in the study group (22.3% vs. 7.4%).

3.2 Patch test results.

PT results with the DKG baseline series are presented in table 2. The composition of DKG PT series changed during the 20-year study period and test concentrations of certain allergens changed, resulting in varying numbers of patients tested with each single allergen. There were only three allergens with significantly increased sensitization rates in the study group, compared to the two control groups: epoxy resin, methylisothiazolinone (MI) and methylchloroisothiazolinone (MCI)/MI. Reaction frequencies to other typical occupational painters' allergens (printed in *italics* in table 2) were not significantly increased. In a 2-year analysis, we consistently found considerably higher sensitization rates to MCI/MI and MI in the study group compared to both control groups, respectively (data not shown in detail).

Most of the allergens considered to be occupationally relevant for painters are part of the DKG baseline series, the DKG resins and glues series, and the DKG industrial biocides series. These had not been tested in every study group patient, resulting in different test frequencies (table S1).

Concerning the DKG resins and glues series, sensitizations to reactive diluents in epoxy resin systems, i.e. glycidyl ethers, were noted most frequently (table 3). In all, 59 patients reacted to at least one of seven glycidyl ethers. Sensitization to epoxy resin hardeners was less frequent, with m-xylylenediamine (MXDA; 8.0% positive reactions) and isophorone diamine (IPDA; 5.9%) being the most prominent allergens. Of the 88 patients sensitized to epoxy resin, 42 (47.7% [37.6 - 58.0])

reacted to at least one glycidyl ether, and 31 (35.2% [26.1 - 45.6]) to at least one of the four amine hardeners (MXDA, IPDA, diethylene triamine, trimethylhexane-1,6-diamine). Reactions to hardeners or reactive diluents also occurred in patients who were not sensitized to epoxy resin. Of the 399 patients with a negative PT to epoxy resin, 11 (2.8%) reacted to at least one glycidyl ether, and 15 (3.8%) to at least one amine hardener. Compared to components of epoxy resin systems, (meth)acrylates only played a minor role as sensitizers.

Among DKG industrial biocides (table 4), benzisothiazolinone (BIT; 6.8% positive reactions) and octylisothiazolinone (OIT; 6.3%) were the leading allergens.

Isocyanates were not included in relevant DKG series during the study period and hence, they have only been patch tested in 126 study group patients, with 1 positive reaction to hexamethylene diisocyanate (0.1% pet.) (Table S2). Twenty-two positive reactions were documented in 472 patients patch tested with 4,4'-diaminodiphenylmethane (MDA). *P*-phenylenediamine (PPD) was patch tested in 197 patients of the study group and elicited 9 positive reactions (4.6% [2.1 - 8.5]). Of 22 patients sensitized to MDA, 6 were patch tested with PPD, 3 of them with a positive test outcome.

The DKG rubber series was patch tested in 274 patients of the study group. Most frequently, reactions to 1,3-diphenylguanidine (1,3-DPG; 3.3% positive reactions) and several thiurams (2.9%) were observed (table S3). Ten patients showed positive PT reactions to at least one thiuram of the DKG rubber series.

In 259 study group patients, material from patients' workplaces had been tested (2392 PTs). In 46 patients, positive reactions were documented and in 16 of these (34.8%), reactions to 18 occupational products were not accompanied by corresponding reactions to standardized PT preparations. These were five protective gloves, three skin creams, three epoxy resin components, four (additives of) paints and varnishes, and three other products (silicone oil, putty, and seal).

Of the study group, 76 patients suffered from face dermatitis. Main sensitizers were epoxy resin and methylisothiazolinone (table S4). 304 of 557 patients were simultaneously patch tested with epoxy resin, MCI/MI, and methylisothiazolinone. This group includes 41 face dermatitis patients. In a multivariate logistic regression analysis, face dermatitis was significantly associated with epoxy resin sensitization (OR 4.59 [2.13 – 9.77]), whereas MI (1.85 [0.63 – 4.91]) and MCI/MI (0.28 [0.06 – 1.13]) were not.

There were 81 females among painters with OD (aged 20 to 59 years, see figure S1) who were registered in the IVDK during the study period. In 16 of 81 (19.8%) patients, lesions were predominantly located in the face. Allergens that elicited positive PT reaction in at least 2 of these 81 patients are listed in table S5. With one exception, the spectrum of sensitizers and corresponding

reaction frequencies were virtually the same as in the study group: nickel sensitization occurred significantly more frequently among female painters with OD (29.6% [19.3 – 41.6]) compared to male painters (4.2% [2.6 - 6.4]).

4. Discussion

This analysis covers 20 years of IVDK data and is, to our knowledge, the largest epidemiological analysis on contact sensitization in painters and varnishers with OD. It demonstrates that allergic contact dermatitis and face dermatitis were significantly more frequent in male painters with OD than in male OD patients working in other occupational fields. This is of importance as both factors worsen the prognosis of remaining in the profession due to limitations in preventive measures.^{3, 22} The data confirms components of epoxy resin systems and isothiazolinones being most important occupational sensitizers in painters.²

4.1 Glues and resins

Painters do not only prepare and handle paints or varnishes, they also process additional construction materials. Epoxy resin chemicals, which could be contained as binders in paints and varnishes,^{1, 23} are increasingly used in epoxy-based coatings (floor, wall, bodywork etc), which explains the high frequency of epoxy resin sensitization in painters. Epoxy resin, patch tested in the DKG baseline series, is a bisphenol type A diglycidyl ether, which serves as a marker for both, bisphenol type A and F sensitization.²⁴

A Danish study, that investigated a small cohort of painters patch tested between 2001 and 2010,¹³ and the last IVDK analysis of painters' patch test data from 1992 to 1998²⁵ had already revealed the significance of epoxy resin as a major contact allergen in painters. In the present analysis, epoxy resin and various glycidyl ethers were the most frequent occupational sensitizers (table 3). Epoxy resin chemicals are volatile allergens⁴ and accordingly, sensitizations to components of epoxy resin systems were frequent in the subgroups of face dermatitis patients (table S4). Moreover, face dermatitis was significantly associated with epoxy resin sensitization in a multivariate regression analysis.

In an IVDK analysis of all PT reactions to epoxy resin and other components of epoxy resin systems between 2002 and 2011, 40% of patients sensitized to epoxy resin had a concomitant PT reaction to glycidyl ethers.²⁶ This is roughly the same dimension as in the current study group (difference not significant). In contrast, concomitant reactions to at least one amine hardener were documented twice as often in painters sensitized to epoxy resin of the current SG (35%) as in the previous IVDK study cohort (19%, difference significant).²⁷ The frequency of face / airborne dermatitis is known to be increased in patients sensitized to hardeners such as MXDA²⁴ which is related to its volatile properties and might be true in painters as well. In patients of the study group not sensitized to epoxy resin, a considerable number of positive reactions to reactive diluents and hardeners of epoxy resin systems were observed confirming that testing only epoxy resin in the baseline series is not

sufficient in these patients. Hence, the DKG resins and glues series should be patch tested in painters if exposure to epoxy-based compounds is at least likely, especially in case of face involvement and even if epoxy resin (1% pet.) showed a negative PT result.

Bisphenol A-glycidyl methacrylate (BIS-GMA) is a special methacrylate and is predominantly known as an allergen in dental material. It is considered to cross-react in patients strongly sensitized to epoxy resin.²⁸ Accordingly, all 19 patients of the study group sensitized to BIS-GMA simultaneously reacted to epoxy resin. Otherwise, sensitizations to (meth)acrylates were rare in painters with OD. Hydroxyethyl acrylate was the most frequent sensitizer of this chemical class (table 3).

Diisocyanates are basic ingredients of 2-component polyurethane foams and thus may be relevant occupational sensitizers in painters. Positive PT reactions to MDA could be both, a marker of diphenylmethane-4,4'-diisocyanate (MDI) sensitization and a marker of sensitization to the chemical group of para amino compounds.²⁹ The latter was possibly the case in about half of the MDA positive study group patients, considering the patch test results for PPD. PTs with isocyanates were usually negative (table S2), which is probably due to their instability.³⁰ Unfortunately, the best isocyanate test preparation, i.e. polymeric diphenylmethane diisocyanate (PMDI) was tested in 4 patients only.³¹

The high rate of positive reactions to benzoyl peroxide must be interpreted with caution as the PT preparation of benzoyl peroxide (1% pet.) is known to frequently cause false positive irritant reactions.³² Occupational relevance of positive PT reactions to benzoyl peroxide is usually untraceable in painters.

4.2 Industrial biocides

MI sensitization is frequent in painters,^{1, 2} and its association to airborne⁴ and face dermatitis³³ is well-known. During the study period, an epidemic of MI sensitization in Europe due to its abundant use in cosmetics occurred, also led to face dermatitis and peaked in 2013/14.³³⁻³⁵ Hence, the distinction between occupational and private exposure might be difficult. In the recent past, MI was banned from leave-on cosmetic products within the EU. However, its use in industrial products is still very common.³⁴ No clear evidence for MCI/MI as an occupational allergen in painters was provided in the last IVDK publication on painters with OD in the 1990s.²⁵ In contrast, Mose et al. were able to show a significant increase of MI sensitization in painters with OD compared to an age- and sex matched control group.¹³ Now, as we have analyzed this large cohort of IVDK patients, we also provide evidence that MI and MCI/MI have been important occupational allergens in painters in the past 20 years (table 2). The main reason is that MI is widely used as a biocide in wall paints.⁶ In a French case series, MI sensitization was associated with airborne dermatitis.¹⁵ Accordingly, sensitization to MI was frequent in our analysis of face dermatitis patients in the study group (table

S4) which is probably related to considerable MI emissions from water-based paints.³⁶ However, in contrast to epoxy resin sensitization, neither sensitization to MI nor to MCI/MI were significantly associated with face dermatitis in a multivariate logistic regression analysis.

Other biocides are also frequently used in water-based paints and varnishes, in particular other isothiazolinones.^{6,37} In line with this, BIT and OIT were the most important allergens from the DKG industrial biocides series (table 4). Therefore, we conclude that the DKG industrial biocides series should be tested in painters with suspected OD. Twenty years ago, formaldehyde sensitization was as frequent as sensitization to MCI/MI in IVDK data of painters with OD.²⁵ In a Danish analysis of register data from 2001 to 2010, formaldehyde and quaternium-15 were found to be significantly increased in painters with OD compared to an age- and sex matched control group.¹³ In our study, sensitizations to formaldehyde (table 2) and formaldehyde releasers (table 4) only played marginal roles. Reactions to methyldibromo glutaronitrile have to be interpreted with caution, as current exposure can largely be excluded and historical sensitization or false positive reactions, especially if it is tested at 0.3% pet., have to be taken into account.³⁸

4.3 Other occupational sensitizers

Overall, sensitization to rubber allergens was less common in painters with OD than reported for other professions, e.g. nurses.³⁹ In the IVDK study of the 1990s, sensitization to thiuram mix was significantly more common in painters with OD compared to painters without OD.²⁵ In the present study, sensitization to thiuram mix was rather infrequent (table 2) and 1,3-DPG was the most prevalent single rubber chemical (table S3). PT results with 1,3-DPG (1% pet.) have to be interpreted with caution as this test preparation is known to elicit doubtful or irritant reactions quite frequently.⁴⁰ Painters use protective gloves rather infrequent in comparison to other professions.⁵ Hence, occupationally used protective gloves were patch tested in four of nine patients sensitized to 1,3-DPG and only one patient reacted positively (data not shown in detail). It might be interesting to investigate whether rubber gloves or other materials represent important allergen sources for vulcanizing agents in painters with OD.

Patch testing patients' own brought-in materials from workplaces in addition to standardized PT preparations displayed a complementary diagnostic value in about one third of the study group patients. As these were tested in merely half of the patients, more relevant occupational sensitizations might have been identified if such materials had been tested in every painter with suspected OD.

4.4 Limitations

We focused on male painters in our study to ensure comparability to the control groups without designing them artificially. Nevertheless, we were able to demonstrate that occupational sensitization spectra did not substantially differ between the sexes (please compare tables 2 and S5). Nickel sensitization, the only sensitization significantly more frequent in female than in male painters with OD, is usually acquired non-occupationally and the connection to cobalt sensitization was already established.⁴¹ The presented data suggests that the current composition of DKG PT series is sufficient for diagnosing or excluding occupational allergic contact dermatitis in both male and female painters.

5. Conclusions

- male painters with OD are characterized by a high share of allergic contact dermatitis and face dermatitis
- Epoxy resin, MI and MCI/MI represent most important occupational sensitizers in painters.
- Epoxy resin is major allergen in painters with occupational face dermatitis.
- Considering exposure and sensitization spectrum, the baseline series, resins and glues series, and industrial biocides series should be tested in painters with suspected OD.
- Patch testing patients' own material should be considered in all painters with suspected OD.

References

1. Hillen U, Bauer A. Contact Allergy to Paint and Lacquers. In: Johansen JD, Mahler V, Lepoittevin J-P, Frosch PJ. Contact Dermatitis. 6th ed. Switzerland: Springer Nature; 2021. p. 1083-91.
2. Law RM, Maibach HI. Painters, Lacquerers, and Varnishers in Occupational Dermatology. In: John SM, Johansen JD, Rustemeyer T, Elsner P, Maibach HI. Kanerva's Occupational Dermatology. 3rd ed. Switzerland: Springer Nature; 2020. p. 2173-81.
3. Brans R, Schroder-Kraft C, Skudlik C, John SM, Geier J. Tertiary prevention of occupational skin diseases: Prevalence of allergic contact dermatitis and pattern of patch test results. Contact Dermatitis. 2019;80(1):35-44.
4. Breuer K, Uter W, Geier J. Epidemiological data on airborne contact dermatitis - results of the IVDK. Contact Dermatitis. 2015;73(4):239-47.
5. Schubert S, Geier J, Skudlik C, Reich A, Hansen A, Buhl T, et al. Relevance of contact sensitizations in occupational dermatitis patients with special focus on patch testing of workplace materials. Contact Dermatitis. 2020;83(6):475-86.
6. Thomsen AV, Schwensen JF, Bossi R, Banerjee P, Gimenez-Arnau E, Lepoittevin JP, et al. Isothiazolinones are still widely used in paints purchased in five European countries: a follow-up study. Contact Dermatitis. 2018;78(4):246-53.
7. Schwensen JF, Menne T, Andersen KE, Sommerlund M, Johansen JD. Occupations at risk of developing contact allergy to isothiazolinones in Danish contact dermatitis patients: results from a Danish multicentre study (2009-2012). Contact Dermatitis. 2014;71(5):295-302.
8. Mose AP, Frost S, Ohlund U, Andersen KE. Allergic contact dermatitis from octylisothiazolinone. Contact Dermatitis. 2013;69(1):49-52.
9. Schwensen JF, Friis UF, Menne T, Flyvholm MA, Johansen JD. Contact allergy to preservatives in patients with occupational contact dermatitis and exposure analysis of preservatives in registered chemical products for occupational use. Int Arch Occup Environ Health. 2017;90(4):319-33.
10. Romyhr O, Nyfors A, Leira HL, Smedbold HT. Allergic contact dermatitis caused by epoxy resin systems in industrial painters. Contact Dermatitis. 2006;55(3):167-72.
11. Aalto-Korte K, Koskela K, Pesonen M. 12-year data on skin diseases in the Finnish Register of Occupational Diseases II: Risk occupations with special reference to allergic contact dermatitis. Contact Dermatitis. 2020;82(6):343-9.
12. Aalto-Korte K, Pesonen M, Suuronen K. Occupational allergic contact dermatitis caused by epoxy chemicals: occupations, sensitizing products, and diagnosis. Contact Dermatitis. 2015;73(6):336-42.
13. Mose AP, Lundov MD, Zachariae C, Menne T, Veien NK, Laurberg G, et al. Occupational contact dermatitis in painters: an analysis of patch test data from the Danish Contact Dermatitis Group. Contact Dermatitis. 2012;67(5):293-7.
14. Christiansen MS, Agner T, Ebbeltoft NE. Long-lasting allergic contact dermatitis caused by methylisothiazolinone in wall paint: A case report. Contact Dermatitis. 2018;79(2):112-3.
15. Amsler E, Aerts O, Raison-Peyron N, Debons M, Milpied B, Giordano-Labadie F, et al. Airborne allergic contact dermatitis caused by isothiazolinones in water-based paints: a retrospective study of 44 cases. Contact Dermatitis. 2017;77(3):163-70.
16. Hillen U, Brehler R, Dickel H, Eck E, Geier J, Koch P, et al. Berufsspezifische Epikutantestung bei Malern und Lackierern - Empfehlungen der Arbeitsgruppe "Berufs-Testreihen" der Deutschen KOntaktallergie-Gruppe. Dermatologie in Beruf und Umwelt. 2006;54(2):47-52.
17. Schnuch A, Geier J, Lessmann H, Arnold R, Uter W. Surveillance of contact allergies: methods and results of the Information Network of Departments of Dermatology (IVDK). Allergy. 2012;67(7):847-57.
18. Uter W, Mackiewicz M, Schnuch A, Geier J. Interne Qualitätssicherung von Epikutantest-Daten des multizentrischen Projektes „Informationsverbund Dermatologischer Kliniken“ (IVDK). Dermatologie in Beruf und Umwelt. 2005;53:107-14.

- Accepted Article
19. Uter W, Schnuch A, Gefeller O, Allergies EwgESSoC. Guidelines for the descriptive presentation and statistical analysis of contact allergy data. *Contact Dermatitis*. 2004;51(2):47-56.
 20. Mahler V, Nast A, Bauer A, Becker D, Brasch J, Breuer K, et al. S3 guidelines: Epicutaneous patch testing with contact allergens and drugs - Short version, Part 1. *J Dtsch Dermatol Ges*. 2019;17(10):1076-93.
 21. Mahler V, Nast A, Bauer A, Becker D, Brasch J, Breuer K, et al. S3 Guidelines: Epicutaneous patch testing with contact allergens and drugs - Short version, Part 2. *J Dtsch Dermatol Ges*. 2019;17(11):1187-207.
 22. Caroe TK, Ebbehøj NE, Bonde JP, Agner T. Occupational hand eczema and/or contact urticaria: factors associated with change of profession or not remaining in the workforce. *Contact Dermatitis*. 2018;78(1):55-63.
 23. Hillen U, Böckler M, Boveleth W, Goergens U, Poppe M, Woeste W, et al. Allergenexposition im Maler- und Lackierberuf: Allergenspektren in Farben und Lacken. *Dermatologie in Beruf und Umwelt*. 2004;52(3):113-25.
 24. Higgins C, Cahill J, Jolanki R, Nixon R. Epoxy Resins. In: John SM, Johansen JD, Rustemeyer T, Elsner P, Maibach HI. *Kanerva's Occupational Dermatology*. 3rd ed. Switzerland: Springer Nature; 2020. p. 757-88.
 25. Hillen U, Uter W, Goergens U, Goos M. Berufliche Kontaktallergien bei Malern und Lackierern. *Dermatol Beruf Umwelt / Occup Environ Dermatol*. 2001;49:263-8.
 26. Geier J, Lessmann H, Hillen U, Skudlik C, Jappe U. Sensitization to reactive diluents and hardeners in epoxy resin systems. IVDK data 2002-2011. Part II: concomitant reactions. *Contact Dermatitis*. 2016;74(2):94-101.
 27. Geier J, Lessmann H, Hillen U, Skudlik C, Jappe U. Sensitization to reactive diluents and hardeners in epoxy resin systems. IVDK data 2002-2011. Part I: reaction frequencies. *Contact Dermatitis*. 2016;74(2):83-93.
 28. Geier J, Lessmann H, Uter W, Schnuch A. Are concomitant patch test reactions to epoxy resin and BIS-GMA indicative of cross-reactivity? *Contact Dermatitis*. 2007;57(6):376-80.
 29. Geier J, Lessmann H. Wie ist eine positive Epikutantestreaktion auf 4,4'-Diaminodiphenylmethan zu beurteilen? *Dermatologie in Beruf und Umwelt*. 2017;65(4):146-57.
 30. Frick-Engfeldt M, Zimerson E, Karlsson D, Marand A, Skarping G, Isaksson M, et al. Chemical analysis of 2,4-toluene diisocyanate, 1,6-hexamethylene diisocyanate and isophorone diisocyanate in petrolatum patch-test preparations. *Dermatitis*. 2005;16(3):130-5.
 31. Frick-Engfeldt M, Isaksson M, Zimerson E, Bruze M. How to optimize patch testing with diphenylmethane diisocyanate. *Contact Dermatitis*. 2007;57(3):138-51.
 32. Ockenfels HM, Uter W, Lessmann H, Schnuch A, Geier J. Patch testing with benzoyl peroxide: reaction profile and interpretation of positive patch test reactions. *Contact Dermatitis*. 2009;61(4):209-16.
 33. Uter W, Geier J, Bauer A, Schnuch A. Risk factors associated with methylisothiazolinone contact sensitization. *Contact Dermatitis*. 2013;69(4):231-8.
 34. Schnuch A, Schubert S, Lessmann H, Geier J, IvdK. The methylisothiazolinone epidemic goes along with changing patients' characteristics - After cosmetics, industrial applications are the focus. *Contact Dermatitis*. 2020;82(2):87-93.
 35. Geier J, Lessmann H, Schnuch A, Uter W. Recent increase in allergic reactions to methylchloroisothiazolinone/methylisothiazolinone: is methylisothiazolinone the culprit? *Contact Dermatitis*. 2012;67(6):334-41.
 36. Lundov MD, Kolarik B, Bossi R, Gunnarsen L, Johansen JD. Emission of isothiazolinones from water-based paints. *Environ Sci Technol*. 2014;48(12):6989-94.
 37. Aerts O, Goossens A, Lambert J, Lepoittevin JP. Contact allergy caused by isothiazolinone derivatives: an overview of non-cosmetic and unusual cosmetic sources. *Eur J Dermatol*. 2017;27(2):115-22.

38. Schnuch A, Schubert S, Geier J, IvdK. Clinicians vs. epidemiologists: patch testing with methyldibromo glutaronitrile as a controversial issue. *J Eur Acad Dermatol Venereol*. 2019;33(6):e242-e4.
39. Molin S, Bauer A, Schnuch A, Geier J. Occupational contact allergy in nurses: results from the Information Network of Departments of Dermatology 2003-2012. *Contact Dermatitis*. 2015;72(3):164-71.
40. Geier J, Lessmann H, Mahler V, Pohrt U, Uter W, Schnuch A. Occupational contact allergy caused by rubber gloves--nothing has changed. *Contact Dermatitis*. 2012;67(3):149-56.
41. Uter W, Lares Filon F, Rui F, Balato A, Wilkinson M, Krecisz B, et al. ESSCA results with nickel, cobalt and chromium, 2009-2012. *Contact Dermatitis*. 2016;75(2):117-21.

Table 1. Population characteristics of the study group (SG; male painters with occupational dermatitis, aged 20-59), control group1 (CG1; men with occupational dermatitis, aged 20-59, who had never worked as painter), and control group 2 (CG2; male painters without occupational dermatitis, aged 20-59).

MOAHLFA-Index		SG (n=557)		CG1 (n=13862)		CG2 (n=422)	
		count	percent	count	percent	count	percent
Male *	M	557	100.0	13862	100.0	422	100.0
Occupational dermatitis *	O	557	100.0	13862	100.0	0	0.0
Past or present atopic dermatitis	A	118	21.2 [18.0 - 24.8]	3655	26.4 [25.6 - 27.1]	78	18.5 [15.1 - 22.5]
Hand dermatitis	H	364	65.4 [61.3 - 69.2]	11018	79.5 [78.8 - 80.2]	148	35.1 [30.7 - 39.7]
Leg dermatitis	L	8	1.4 [0.7 - 2.8]	125	0.9 [0.8 - 1.1]	28	6.6 [4.6 - 9.4]
Face dermatitis	F	76	13.6 [11.0 - 16.8]	727	5.2 [4.9 - 5.6]	57	13.5 [10.6 - 17.1]
Age >= 40 years *	A	304	54.6 [50.4 - 58.7]	7839	56.6 [55.7 - 57.4]	241	57.1 [52.2 - 61.9]
Main Diagnoses		SG (n=557)		CG1 (n=13862)		CG2 (n=422)	
		count	percent	count	percent	count	percent
Allergic contact dermatitis		237	42.5 [38.5 - 46.7]	4450	32.1 [31.3 - 32.9]	72	17.1 [13.8 - 20.9]
Chronic irritant contact dermatitis		85	15.3 [12.5 - 18.5]	3422	24.7 [24.0 - 25.4]	33	7.8 [5.6 - 10.8]
Atopic dermatitis (current)		35	6.3 [4.6 - 8.6]	1240	8.9 [8.5 - 9.4]	31	7.3 [5.2 - 10.2]
Dyshidrotic eczema		32	5.7 [4.1 - 8.0]	883	6.4 [6.0 - 6.8]	36	8.5 [6.2 - 11.6]
Hyperkeratotic eczema		31	5.6 [4.0 - 7.8]	1013	7.3 [6.9 - 7.8]	13	3.1 [1.8 - 5.2]
Airborne dermatitis		23	4.1 [2.8 - 6.1]	164	1.2 [1.0 - 1.4]	1	0.2 [0.0 - 1.4]
Suspected allergen sources (up to 3 entries per case possible)		SG (n=577)		CG1 (n=13862)		CG2 (n=422)	
		count	percent	count	percent	count	percent
Paints, varnishes		383	68.8 [64.8 - 72.5]	562	4.1 [3.7 - 4.4]	169	40.0 [35.5 - 44.8]
Glues, adhesives		100	18.0 [15.0 - 21.4]	1116	8.1 [7.6 - 8.5]	30	7.1 [5.0 - 10.0]
Gloves		89	16.0 [13.2 - 19.3]	3366	24.3 [23.6 - 25.0]	40	9.5 [7.0 - 12.7]
Paint (freshly painted rooms)		83	14.9 [12.2 - 18.1]	55	0.4 [0.3 - 0.5]	36	8.5 [6.2 - 11.6]
Construction material (cement, tile cement etc.)		81	14.5 [11.9 - 17.7]	1653	11.9 [11.4 - 12.5]	30	7.1 [5.0 - 10.0]
Other rubber		44	7.9 [5.9 - 10.4]	1924	13.9 [13.3 - 14.5]	33	7.8 [5.6 - 10.8]
Solvents		44	7.9 [5.9 - 10.4]	359	2.6 [2.3 - 2.9]	20	4.7 [3.1 - 7.2]
Leave-on cosmetics		41	7.4 [5.5 - 9.8]	1720	12.4 [11.9 - 13.0]	94	22.3 [18.6 - 26.5]
Plastics		37	6.6 [4.9 - 9.0]	781	5.6 [5.3 - 6.0]	16	3.8 [2.4 - 6.1]
Other chemicals		34	6.1 [4.4 - 8.4]	773	5.6 [5.2 - 6.0]	10	2.4 [1.3 - 4.3]

* affected by group definition.

Table 2. Patch test results with allergens of the DKG baseline series in the study group (SG; male painters with occupational dermatitis, aged 20-59), control group 1 (CG1; men with occupational dermatitis, aged 20-59, who had never worked as painters), and control group 2 (CG2; male painters without occupational dermatitis, aged 20-59). Vehicle is petrolatum unless aqua (aq) is specified. *Italic names indicate relevant occupational painter allergens according to [2,3,4]. Allergens with significantly increased reaction frequency in SG are highlighted in bold.* We limited the presentation to those allergen preparations which elicited positive reactions in at least 3 (0.5%) patients of the study group.

		SG (n=557)			CG1 (n=13862)			CG2 (n=422)		
Substance	Conc.	N test	N pos	% pos [95%-CI]	N test	N pos	% pos [95%-CI]	N test	N pos	% pos [95%-CI]
<i>Epoxy resin</i>	1%	498	88	17.7 [14.4 - 21.3]	12079	620	5.1 [4.7 - 5.5]	365	11	3.0 [1.5 - 5.3]
<i>Methylisothiazolinone (aq)</i>	0.05%	316	69	21.8 [17.4 - 26.8]	7591	413	5.4 [4.9 - 6.0]	198	9	4.5 [2.1 - 8.5]
<i>MCI/MI (aq)</i>	0.01%	501	60	12.0 [9.3 - 15.1]	12320	530	4.3 [4.0 - 4.7]	363	12	3.3 [1.7 - 5.7]
Balsam of Peru (<i>Myroxylon pereirae</i>)	25%	504	30	6.0 [4.1 - 8.4]	12341	584	4.7 [4.4 - 5.1]	365	25	6.8 [4.5 - 9.9]
<i>Cobalt (II)-chloride</i>	1%	502	25	5.0 [3.2 - 7.3]	12312	710	5.8 [5.4 - 6.2]	365	7	1.9 [0.8 - 3.9]
<i>Nickel (II)-sulfate</i>	5%	497	21	4.2 [2.6 - 6.4]	12251	769	6.3 [5.9 - 6.7]	363	29	8.0 [5.4 - 11.3]
<i>Potassium dichromate</i>	0.5%	503	20	4.0 [2.4 - 6.1]	12302	908	7.4 [6.9 - 7.9]	366	8	2.2 [0.9 - 4.3]
Fragrance mix	8%	500	19	3.8 [2.3 - 5.9]	12253	614	5.0 [4.6 - 5.4]	365	17	4.7 [2.7 - 7.4]
<i>Thiuram mix</i>	1%	501	16	3.2 [1.8 - 5.1]	12283	576	4.7 [4.3 - 5.1]	366	5	1.4 [0.4 - 3.2]
<i>MDBGN</i>	0.3%	176	14	8.0 [4.4 - 13.0]	5297	293	5.5 [4.9 - 6.2]	128	7	5.5 [2.2 - 10.9]
Fragrance mix II	14%	416	14	3.4 [1.9 - 5.6]	9940	318	3.2 [2.9 - 3.6]	294	9	3.1 [1.4 - 5.7]
Propolis	10%	503	13	2.6 [1.4 - 4.4]	12333	291	2.4 [2.1 - 2.6]	364	7	1.9 [0.8 - 3.9]
<i>Colophony (Rosin)</i>	20%	498	12	2.4 [1.3 - 4.2]	12348	580	4.7 [4.3 - 5.1]	365	8	2.2 [1.0 - 4.3]
<i>MDBGN</i>	0.2%	271	11	4.1 [2.0 - 7.1]	5956	186	3.1 [2.7 - 3.6]	187	2	1.1 [0.1 - 3.8]
<i>Oil of turpentine</i>	10%	502	8	1.6 [0.7 - 3.1]	12303	178	1.4 [1.2 - 1.7]	362	1	0.3 [0.0 - 1.5]
IPBC	0.2%	391	8	2.0 [0.9 - 4.0]	9729	163	1.7 [1.4 - 2.0]	253	3	1.2 [0.2 - 3.4]
Lanolin alcohols	30%	503	7	1.4 [0.6 - 2.8]	12355	180	1.5 [1.3 - 1.7]	364	6	1.6 [0.6 - 3.6]
Paraben mix	16%	501	6	1.2 [0.4 - 2.6]	12301	135	1.1 [0.9 - 1.3]	364	2	0.5 [0.1 - 2.0]
<i>Formaldehyde (aq)</i>	1%	504	5	1.0 [0.3 - 2.3]	12363	226	1.8 [1.6 - 2.1]	364	1	0.3 [0.0 - 1.5]
Mercaptobenzothiazole	2%	447	4	0.9 [0.2 - 2.3]	10986	182	1.7 [1.4 - 1.9]	327	2	0.6 [0.1 - 2.2]
Mercapto mix (CBS, MBTS, MOR)	1%	501	4	0.8 [0.2 - 2.0]	12198	198	1.6 [1.4 - 1.9]	363	4	1.1 [0.3 - 2.8]
IPPD	0.1%	504	3	0.6 [0.1 - 1.7]	12343	214	1.7 [1.5 - 2.0]	365	3	0.8 [0.2 - 2.4]

HICC	5%	486	3	0.6 [0.1 - 1.8]	11829	196	1.7 [1.4 - 1.9]	344	3	0.9 [0.2 - 2.5]
Bronopol	0.5%	450	3	0.7 [0.1 - 1.9]	11090	105	0.9 [0.8 - 1.1]	321	2	0.6 [0.1 - 2.2]
Jasmine absolute	5%	316	3	0.9 [0.2 - 2.7]	7315	71	1.0 [0.8 - 1.2]	204	0	0.0 [0.0 - 1.8]
Cetostearyl alcohol	20 %	502	2	0.4 [0.0 - 1.4]	365	0	0.0 [0.0 - 1.0]	12324	55	0.4 [0.3 - 0.6]
Zinc diethyldithiocarbamate (ZDEC)	1 %	505	2	0.4 [0.0 - 1.4]	365	0	0.0 [0.0 - 1.0]	12354	127	1.0 [0.9 - 1.2]
Compositae mix	6 %	100	2	2.0 [0.2 - 7.0]	84	2	2.4 [0.3 - 8.3]	2931	59	2.0 [1.5 - 2.6]
Ylang Ylang oil	10 %	328	2	0.6 [0.1 - 2.2]	206	6	2.9 [1.1 - 6.2]	7343	109	1.5 [1.2 - 1.8]
Compositae mix II	5 %	242	2	0.8 [0.1 - 3.0]	153	1	0.7 [0.0 - 3.6]	5447	74	1.4 [1.1 - 1.7]
Bufexamac	5 %	339	1	0.3 [0.0 - 1.6]	266	1	0.4[0.0 - 2.1]	8530	46	0.5 [0.4 - 0.7]
Sandalwood oil	10 %	316	1	0.3 [0.0 - 1.8]	204	1	0.5 [0.0 - 2.7]	7320	60	0.8 [0.6 - 1.1]
Mercaptobenzothiazole	1 %	52	0	0.0 [0.0 - 6.8]	30	0	0.0 [0.0 -11.6]	1212	21	1.7 [1.1 - 2.6]
PTBFR	1 %	357	0	0.0 [0.0 - 1.0]	277	0	0.0 [0.0 - 1.3]	9029	59	0.7 [0.5 - 0.8]
Compositae mix	5 %	146	0	0.0 [0.0 - 2.5]	113	0	0.0 [0.0 - 3.2]	3597	58	1.6 [1.2 - 2.1]

95% CI, 95% confidence interval; DKG, German Contact Dermatitis Research Group; CBS, *N*-cyclohexyl-2-benzothiazyl sulfenamide; HICC, hydroxyisohexyl 3-cyclohexene carboxaldehyde; IPBC, Iodopropynylbutyl carbamate; IPPD, *N*-isopropyl-*N*-phenyl-*p*-phenylenediamine; MBT, 2-mercaptobenzothiazole; MBTS, Dibenzothiazyl disulfide; MCI, methylchloroisothiazolinone; MDBGN, methyldibromo glutaronitrile; MI, methylisothiazolinone; MOR, morpholinylmercaptobenzothiazole; PTBFR, *p*-tert.-Butylphenol formaldehyde resin; ZDEC, Zinc diethyldithiocarbamate.

Table 3. Patch test results with the DKG resins and glues series in the study group (male painters with occupational dermatitis, aged 20-59). Vehicle is petrolatum.

Substance	Concentration	n tested	n positive	% pos [95%-CI]
Epoxy resin systems				
1,6-Hexanediol diglycidylether	0.25 %	354	38	10.7 [7.7 - 14.4]
1,4-Butanediol diglycidylether	0.25 %	354	29	8.2 [5.6 - 11.6]
m-Xylylenediamine (MXDA)	0.1 %	311	25	8.0 [5.3 - 11.6]
Phenylglycidyl ether	0.25 %	423	32	7.6 [5.2 - 10.5]
Isophorone diamine (IPDA)	0.5 %	422	25	5.9 [3.9 - 8.6]
p-tert.-Butylphenyl glycidylether	0.25 %	268	13	4.9 [2.6 - 8.2]
Trimethylhexane-1,6-diamine	0.5 %	302	12	4.0 [2.1 - 6.8]
Cresylglycidyl ether	0.25 %	422	13	3.1 [1.7 - 5.2]
Butylglycidyl ether	0.25 %	424	13	3.1 [1.6 - 5.2]
Diethylene triamine	1 %	334	7	2.1 [0.8 - 4.3]
Trimethylolpropane triglycidyl ether	0.25 %	311	4	1.3 [0.4 - 3.3]
Diethylene triamine	0.5 %	90	0	0.0 [0.0 - 4.0]
(Meth)Acrylates				
Bisphenol A-glycidyl methacrylate (BIS-GMA)	2 %	421	19	4.5 [2.7 - 7.0]
Hydroxyethyl acrylate	0.1 %	420	8	1.9 [0.8 - 3.7]
2-Hydroxyethyl methacrylate (HEMA)	1 %	417	4	1.0 [0.3 - 2.4]
2-Hydroxypropyl methacrylate (HPMA)	2 %	415	1	0.2 [0.0 - 1.3]
Methylmethacrylate (MMA)	2 %	417	1	0.2 [0.0 - 1.3]
Ethylenglycol dimethacrylate	2 %	418	1	0.2 [0.0 - 1.3]
Triethyleneglycol dimethacrylate (TEGDMA)	2 %	417	0	0.0 [0.0 - 0.9]
Others				
4,4'-Diaminodiphenylmethane (MDA)	0.5 %	422	21	5.0 [3.1 - 7.5]
Benzoyl peroxide	1 %	422	19	4.5 [2.7 - 6.9]
p-tert.-Butylcatechol	0.25 %	391	6	1.5 [0.6 - 3.3]
Phenol formaldehyde resin (Novolak)	5 %	424	2	0.5 [0.1 - 1.7]
4,4'-Dihydroxydiphenyl	0.1 %	255	0	0.0 [0.0 - 1.4]

Table 4: Patch test results with the DKG industrial biocides series in the study group (male painters with occupational dermatitis, aged 20-59). Vehicle is petrolatum unless aqua (aq) is specified.

Substance	Concentration	n tested	n positive	% pos [95%-CI]
1,2-Benzisothiazolin-3-one, sodium salt	0.1 %	192	13	6.8 [3.7 - 11.3]
Octylisothiazolinone	0.025 %	190	12	6.3 [3.3 - 10.8]
Iodopropynylbutyl carbamate (IPBC)	0.2 %	191	5	2.6 [0.9 - 6.0]
Methylene-bis(methyloxazolidine)	1 %	190	3	1.6 [0.3 - 4.5]
Bronopol	0.5 %	175	3	1.7 [0.4 - 4.9]
4,4-Dimethyloxazolidine/..(Bioban CS 1135)	1 %	190	3	1.6 [0.3 - 4.5]
(Nitrobutyl)morpholine/.. (Bioban P 1487)	1 %	191	3	1.6 [0.3 - 4.5]
Benzyl hemiformal	1 %	190	2	1.1 [0.1 - 3.8]
Chlorocresol	1 %	150	2	1.3 [0.2 - 4.7]
7-Ethylbicyclooxazolidine	1 %	190	2	1.1 [0.1 - 3.8]
Chloroxylonol	1 %	136	1	0.7 [0.0 - 4.0]
Sodium-2-pyridinethiol-1-oxide (aq)	0.1 %	190	0	0.0 [0.0 - 1.9]

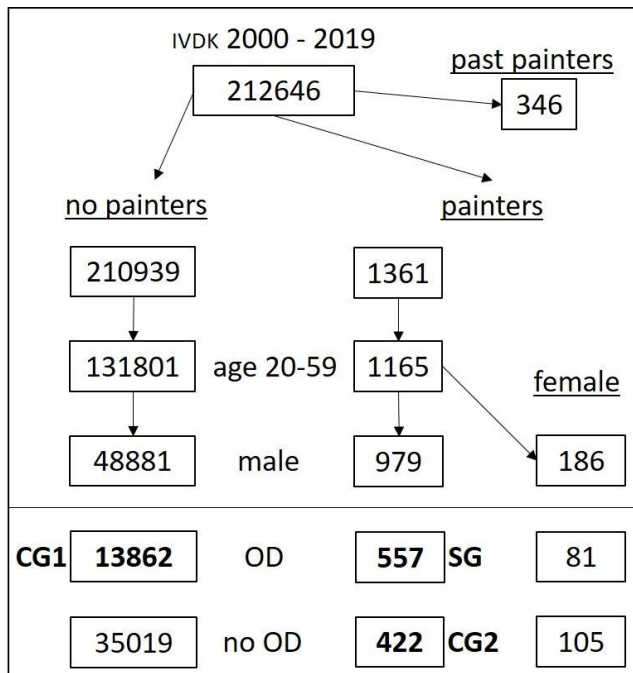


Figure S1: Patient selection. CG1, control group 1 (men with occupational dermatitis, aged 20-59, who had never worked as painters); CG2, control group 2 (male painters without occupational dermatitis, aged 20-59); SG, study group (male painters with occupational dermatitis, aged 20-59).

Table S1. Patch test frequency of most frequently selected DKG patch test series in the study group (SG; male painters with occupational dermatitis, aged 20-59), control group 1 (CG1; men with occupational dermatitis, aged 20-59, who had never worked as painters), and control group 2 (CG2; male painters without occupational dermatitis, aged 20-59).

DKG patch test series	SG (n=557)	CG1 (n=13862)	CG2 (n=422)
Baseline	93.4%	91.7%	88.9%
Resins and glues	77.7%	28.1%	49.5%
Preservatives (topical preparations)	60.9%	64.9%	54.5%
Ointment bases	59.2%	64.8%	54.5%
Rubber	49.6%	56.8%	25.1%
Industrial biocides	34.6%	21.6%	16.4%

DKG, German Contact Dermatitis Research Group.

Table S2: Patch test results with isocyanates and 4,4'-diaminodiphenylmethane (MDA) in the study group. Vehicle is petrolatum.

Substance	Conc	N test	N pos	% pos [95%-CI]
4,4'-Diaminodiphenylmethane (MDA)	0.5%	472	22	4.7 [2.9 - 7.0]
Diphenylmethane-4,4'-diisocyanate (MDI)	#	123	0	0.0 [0.0 - 3.0]
Toluene-2,4-diisocyanate (TDI)	#	121	0	0.0 [0.0 - 3.0]
Hexamethylene diisocyanate (HDI)	0.1%	33	1	3.0 [0.1 - 15.8]
Isophorone diisocyanate	1 %	21	0	0.0 [0.0 - 16.1]
Polymeric diphenylmethane diisocyanate (PMDI)	2 %	4	0	0.0 [0.0 - 49.0]

DKG, German Contact Dermatitis Research Group; # patch tested at concentrations from 0.1% to 2.0%.

Table S3: Patch test results obtained with the DKG rubber series in male painters with occupational dermatitis, aged 20-59.

Substance	N test	N pos	% pos [95%-CI]
1,3-Diphenylguanidine (1,3-DPG)	274	9	3.3 [1.5 - 6.1]
Tetramethylthiuramdisulfide (TMTD)	272	8	2.9 [1.3 - 5.7]
Tetramethylthiurammonosulfide (TMTM)	273	8	2.9 [1.3 - 5.7]
Tetraethylthiuramdisulfide (Disulfiram)(TETD)	274	8	2.9 [1.3 - 5.7]
Mercaptobenzothiazole	236	3	1.3 [0.3 - 3.7]
p-tert.-Butylcatechol	255	3	1.2 [0.2 - 3.4]
N,N'-Diphenyl-p-phenylene diamine (DPPD)	273	2	0.7 [0.1 - 2.6]
Cyclohexyl thiophthalimide	272	2	0.7 [0.1 - 2.6]
Dipentamethylen thiuramdisulfide	274	1	0.4 [0.0 - 2.0]
Methenamine (hexamethylene tetramine)	273	1	0.4 [0.0 - 2.0]
Monobenzene	273	1	0.4 [0.0 - 2.0]
Morpholinylmercaptobenzothiazole	274	1	0.4 [0.0 - 2.0]
N-Cyclohexyl-2-benzothiazyl sulfenamide	274	1	0.4 [0.0 - 2.0]
N-Isopropyl-N'-phenyl-p-phenylene diamine (IPPD)	265	1	0.4 [0.0 - 2.1]
Zinc diethyldithiocarbamate (ZDEC)	265	1	0.4 [0.0 - 2.1]
Dibenzothiazyl disulfide (MBTS)	274	1	0.4 [0.0 - 2.0]
4,4'-Dihydroxydiphenyl	260	0	0.0 [0.0 - 1.4]
Dibutyl thiourea	274	0	0.0 [0.0 - 1.3]
Diphenyl thiourea	274	0	0.0 [0.0 - 1.3]
Ethylene diamine-di-HCl	271	0	0.0 [0.0 - 1.4]
Zinc dibutyldithiocarbamate (ZDBC)	271	0	0.0 [0.0 - 1.4]
Zinc dibenzylthiocarbamate	251	0	0.0 [0.0 - 1.5]

DKG, German Contact Dermatitis Research Group.

Table S4: Sensitizers which elicited positive patch test reactions in at least three of 76 face dermatitis patients among male painters with occupational dermatitis, aged 20-59 (study group).

	Face dermatitis patients (n = 76)		
Population characteristics	n	%	
Male* M	76	100.0	
Occupational dermatitis* O	76	100.0	
Past or present atopic dermatitis A	15	19.7	
Hand dermatitis H	0	0.0	
Leg dermatitis L	0	0.0	
Face dermatitis F	76	100.0	
Age >= 40 years* A	43	56.6	
Substance	N test	N pos	% pos [95%-CI]
Epoxy resin	71	28	39.4 [28.0 - 51.7]
Phenylglycidyl ether	65	10	15.4 [7.6 - 26.5]
Bisphenol A-glycidyl methacrylate (BIS-GMA)	63	9	14.3 [6.7 – 25.4]
Methylisothiazolinone	41	8	19.5 [8.8 - 34.9]
1,6-Hexanediol-diglycidyl ether	58	8	13.8 [6.1 - 25.4]
1,4-Butanediol- diglycidyl ether	58	7	12.1 [5.0 - 23.3]
Isophorone diamine (IPDA)	65	6	9.2 [3.5 – 19.0]
Methylchloroisothiazolinone	71	4	5.6 [1.6 – 13.8]
Methylisothiazolinone (MCI/MI)			
4,4'-Diaminodiphenylmethane	65	4	6.2 [1.7 - 15.0]
M-Xylidendiamine (MXDA)	52	4	7.7 [2.1 - 18.5]
Benzoyl peroxide	62	3	4.8 [1.0 - 13.5]
Nickel (II)-sulfate hexahydrate	70	3	4.3 [0.9 - 12.0]
Balsam of Peru (Myroxylon pereirae)	70	3	4.3 [0.9 - 12.0]
Propolis	70	3	4.3 [0.9 - 12.0]
p-tert.-Butylphenyl glycidyl ether	40	3	7.5 [1.6 - 20.4]

* affected by group definition

Table S5. Contact sensitizers which elicited positive patch test reactions in at least 2 of 81 female painters with occupational dermatitis. For better comparison to the study group, only patients between 20 and 59 years of age were selected for analysis.

Substance	N test	N pos	% pos [95%-CI]
Nickel (II)-sulfate	71	21	29.6 [19.3 - 41.6]
Cobalt (II)-chloride	72	9	12.5 [5.9 - 22.4]
Epoxy resin	73	8	11.0 [4.9 - 20.5]
Potassium dichromate	74	6	8.1 [3.0 - 16.8]
Methylisothiazolinone	43	5	11.6 [3.9 - 25.1]
1,4-Butanediol-diglycidyl ether	50	5	10.0 [3.3 - 21.8]
1,6-Hexanediol- diglycidyl ether	50	5	10.0 [3.3 - 21.8]
Phenylglycidyl ether	64	5	7.8 [2.6 - 17.3]
(Chloro)-Methylisothiazolinone (MCI/MI)	74	5	6.8 [2.2 - 15.1]
p-tert-Butylphenyl glycidyl ether	36	4	11.1 [3.1 - 26.1]
Methyldibromo glutaronitrile	62	4	6.5 [1.8 - 15.7]
Diethylene triamine	64	3	4.7 [1.0 - 13.1]
4,4'-Diaminodiphenylmethane	65	3	4.6 [1.0 - 12.9]
Colophony (Rosin)	74	3	4.1 [0.8 - 11.4]
Balsam of Peru (Myroxylon pereirae)	74	3	4.1 [0.8 - 11.4]
Cresylglycidyl ether	65	2	3.1 [0.4 - 10.7]
Fragrance mix	74	2	2.7 [0.3 - 9.4]
Thiuram mix	74	2	2.7 [0.3 - 9.4]

Acknowledgements

We thank the following centres (persons) for contributing data to the analysis (in alphabetical order):

Aachen (J.M. Baron), Aarau (J. Grabbe), Augsburg (A. Ludwig, K. Siedlecki), Bad Reichenhall (K. Strom), Basel (A. Bircher, K. Scherer, K. Hartmann), Berlin B.-Frank. (B. Tebbe, R. Treudler), Berlin BWK (A. Köhler), Berlin Charité (T. Zuberbier, M. Worm), Bern (D. Simon), Bielefeld (I. Effendy), Bochum (Ch. Szliska, M. Straube, H. Dickel), Bochum BGFA (M. Fartasch), Bremen (D. Meyersburg, N. Patsinakidis), Buxtehude (P. Große-Hüttmann, P. Hausenblas), Dermatologikum (V. Martin, K. Reich, K. Breuer, D. Vieluf), Dessau (A. Jung, U. Lippert), Dortmund (P.J. Frosch, B. Mydlach, C. Pirker, R. Herbst, K. Kügler, U. Beiteke), Dresden (G. Richter, R. Aschoff, P. Spornraft-Ragaller), Dresden Friedrichst. (A. Koch), Erlangen (M. Fartasch, M. Hertl, V. Mahler, N. Wagner), Essen (J. Dissemond), Falkenstein (H. Schwantes, D. Vieluf, M. Fischer, M. Gina), Freudenberg (Ch. Szliska), Gera (J. Meyer, H. Grunwald-Delitz, M. Kaatz), Graz (W. Aberer, B. Kränke), Greifswald (M. Jünger), Göttingen (Th. Fuchs, T. Buhl), Halle (G. Gaber, D. Lübke, B. Kreft), Hamburg (M. Kiehn, R. Weißbecher, E. Coors, J. Witte), Hamburg BUK (K. Breuer, U. Seemann, C. Schröder-Kraft), Hannover (T. Schaefer, A. Kapp), Heidelberg (A. Schulze-Dirks, M. Hartmann, U. Jappe, M. Hartmann, K. Schäkel), Heidelberg AKS (H. Dickel, T.L. Diepgen, E. Weisshaar), Heilbronn (H. Löffler, P. Amann), Homburg / Saar (P. Koch, C. Pföhler), Jena (W. Wigger-Alberti, M. Kaatz, S. Schliemann), Kiel (J. Brasch), Krefeld (A. Wallerand, M. Lilie, S. Wassilew), Lausanne (P. Spring, C. Curdin), Leipzig (R. Treudler), Linz (I. Angelova-Fischer), Lippe Detmold (St. Nestoris), Lübeck (J. Grabbe, I. Shimanovich, U. Jappe, K. Hartmann, A. Recke), Mainz (D. Becker), Mannheim (Ch. Bayerl, D. Booken, C.-D. Klemke, W. Ludwig-Peitsch, A. Schmieder), Marburg (I. Effendy, H. Löffler, M. Hertl, W. Pfützner), Minden (J. Hoffmann, R. Stadler), München LMU (T. Oppel, B. Przybilla, P. Thomas, T. Schuh, R. Eben, S. Molin, F. Rueff), München Schwabing (M. Agathos, K. Ramrath, M. Georgi, K. Ramrath, G. Isbary), München TU (J. Rakoski, U. Darsow, T. Biedermann, K. Brockow), Münster (B. Hellweg, R. Brehler, M. Behring), Nürnberg (I. Müller, D. Debus, A. Bachtler, K. Ertner, V. Baur), Oldenburg (M. Padeken, O. Kautz, U. Raap), Osnabrück (W. Uter, S.M. John, H.J. Schwanitz, N. Schürer, H. Dickel, Ch. Skudlik, S.M. John), Prager und Partner (V. Martin, W. Prager), Rostock (H. Heise, J. Trcka), Stuttgart (J. Rieker-Schwiebacher), Tobelbad (D. Wilfinger), Tübingen (G. Lischka, M. Röcken, T. Biedermann, J. Fischer, S. Forchhammer), Ulm (H. Gall, G. Staib, P. Gottlöber), Ulm BWK (H. Pillekamp), Ulm Univ.-Klinik (J. Weiss), Würzburg (J. Arnold, A. Trautmann), Zwickau (B. Knopf, D. Teubner, D. Mechtel), and Zürich (B. Ballmer-Weber, A. Navarini, S. Micaletto, C. Lang).