Allergic contact dermatitis caused by 2-hydroxyethyl methacrylate and ethyl cyanoacrylate contained in cosmetic glues among hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications: A systematic review

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Abstract
Current cosmetic regulations primarily focus on protecting consumers, not the professional user who is subjected to a partly different, and certainly more intense exposure to hazardous substances. Against this background, this systematic review aims to compile and appraise evidence regarding skin toxicity of 2-hydroxyethyl methacrylate (HEMA; CAS no. 212-782-2) and ethyl cyanoacrylate (ECA; CAS no. 7085-85-0) contained in cosmetic glues used among hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications. This systematic review followed the Preferred Reporting Items for Systematic review and Meta-Analysis (PRISMA) 2020 recommendations for reporting systematic reviews and meta-analysis. In total, six publications from six countries were eligible for this systematic review. A meta-analysis revealed that hairdressers and beauticians have a ninefold increased risk of developing contact allergy to HEMA compared with controls who are not hairdressers and beauticians. Results for ECA are lacking. The results of this systematic review clearly show that—regarding contact allergy to acrylates—it is not appropriate to apply risk assessment for consumers to hairdressers and beauticians who occupationally handle cosmetic glues. The regulations in

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1 | INTRODUCTION

Hairdressers and beauticians constitute a high-risk cohort for developing work-related skin damage and consequently occupational skin diseases (OSDs). Hand dermatitis (hand eczema [HE]) is thereby the most common OSD. The most relevant factors that contribute to the pathogenesis of HE in this occupational group are wet work and skin contact with irritants and allergens. This skin strain in everyday working life leads to impairment of the epidermal barrier function concomitant with the induction of a proinflammatory milieu; consequently, the risk of developing occupational contact dermatitis is increased. Initial irritant HE can easily lead to the development of allergic HE due to the fact that allergens penetrate the impaired skin barrier more easily. An adequate risk assessment regarding hazardous substances, namely allergens, is indispensable to initiate appropriate protective measures and to ultimately protect the (skin) health of hairdressers and beauticians.

Occupational exposure is constantly changing due to changing compositions of products at work, which presents a major challenge for conducting risk assessment in the cosmetics sector. While taking the cosmetic products’ instructions of use into account, it is important to consider that hairdressers and beauticians are exposed regularly and for significant hours and long periods to hazardous substances. The European Cosmetics Regulation, adopted in 2009, is primarily focused on protecting consumers, not professional users. The Scientific Committee on Consumer Safety (SCCS) normally does not assess the risk of occupational exposures and therefore almost exclusively deals with ‘consumer’ aspects, targeting the general public. Thereby, occupational risks associated with the use of cosmetic products are not sufficiently recognized. As one consequence, the European Commission is unable to initiate appropriate occupational risk management to adequately protect hairdressers and beauticians. This has to be regarded as highly problematic because OSD does not only entail suffering due to illness on an individual level but also presents a macrosocial problem as it may further result in high medical treatment costs for the social insurance system as well as social consequences such as a necessary occupational change or at worst, a premature withdrawal from the labour market.

Within the framework of the project ‘Promoting the autonomous implementation of the European framework agreement on occupational health and safety in the hairdressing sector’, a series of systematic reviews have been performed. One of the product categories on which a focus has been put is cosmetic glues, used in the beauty sector for applying hair extensions, conducting nail treatments that involve the use of cosmetic (nail) glues/applying nail art, and applying eyelash extensions (Figure 1). 2-Hydroxyethyl methacrylate (HEMA; CAS no. 212-782-2) and ethyl cyanoacrylate (ECA; CAS no. 7085-85-0) were identified as target substances in cosmetic glues. This systematic review aims to compile and appraise clinical evidence regarding skin toxicity of HEMA and ECA contained in cosmetic glues.

2 | METHODS

2.1 | Eligibility criteria

Eligibility criteria for studies to be included in the systematic review are reported following the PECOS (participants, exposure, comparator, outcome, study design) scheme adapted from the CRD’ (Centre for Reviews and Dissemination) guidance for undertaking reviews in health care (Table 1).

2.2 | Registration and protocol

This systematic review has been registered in the International Prospective Register of Systematic Reviews (PROSPERO) under the registration number CRD42021238118. The protocol has been published elsewhere. No amendments to the information provided at registration or in the protocol were made.

2.3 | Information sources

Systematic searches were conducted within the electronic databases PubMed/MEDLINE and Web of Science Core Collection (WoS). Assessment of risk of bias (ROB) within included studies and assessment of quality of evidence have been described in the protocol for this systematic review. As we expected large heterogeneity in methods and outcomes, we conducted a narrative synthesis of results instead of a meta-analysis, except where quantitative pooling was feasible.

2.4 | Search strategy

Searches were performed in February 2021. Furthermore, we hand searched the bibliographies of all studies identified through the
electronic database search and meeting the inclusion criteria. We also performed forward snowballing by using the six most important references identified, and checked all references citing any of these publications. This citation analysis was performed based on the WoS database. We used English search terms only.

Generally, we searched for title, abstract, and keywords. Only accepted publications after 1999 (ie, 2000 and following) were considered.

### 2.5 | Selection process

For one search query, the search results were exported from MEDLINE and WoS in a suitable format and imported into Zotero libraries, documenting the number of references contributed by each export/import set. In the Zotero library, bibliographical duplicates were identified and the entry including less information (eg, no abstract) were discarded. In case of discordant results, the entry was reviewed by a third experienced reviewer and a final decision was made. Reasons for noninclusion were documented, and summarized at the end for use in the Preferred Reporting Items for Systematic review and Meta-Analysis (PRISMA) for systematic review protocols (PRISMA-P) flow chart.

The final set of references eligible for full-text screening by two reviewers (C.S. and P.W.) were imported into a Zotero cloud-based reference database after the initial set of references had been archived. Full-text articles were, again, scrutinized and extracted independently by two reviewers, with a third senior reviewer (S.M.J. or W. U.) consensualizing divergent results between the two initial reviewers. All decisions and reasons leading to the exclusion of studies were documented, providing information on the individual assessments by both initial reviewers and the final decision. At the end of

### FIGURE 1

Usual application of eyelash glue/adhesive onto (A) so-called cluster eyelash extensions and (B) a so-called eyelash band. The eyelash glue is usually placed on the back of the hand and the eyelash extension is then dipped into the glue with the help of tweezers. Oftentimes, the remaining eyelash glue dries on the hand and the residue will only be removed at the end of the working day, thereby exposing the hairdresser or beautician to the substances contained in the cosmetic glue for a considerable amount of time. Exposure might also be given when gloves are worn due to the short break-through times (<10 minutes) of acrylates for most gloves used in the cosmetic sector. Thus, even wearing gloves would not alleviate the high risk of sensitization.

### TABLE 1 | Eligibility criteria following the PECOS scheme

| Criterion       | Inclusion                                                                 | Exclusion            |
|-----------------|---------------------------------------------------------------------------|----------------------|
| Participants    | Hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications, patients, products | None                 |
| Exposure        | Exposure to (an) eligible chemical(s)                                      | n/a                  |
| Comparator      | Clients, consumers, normal population (no or less exposure)               | n/a                  |
| Outcome         | Skin toxicity event (contact allergy, irritancy)                          | n/a                  |
| Study design    | Experimental studies                                                      | Qualitative studies  |
| Observational studies | Case reports                          | Case series           |

Abbreviation: n/a, not applicable.

*Hairdressers and related occupational groups (manicurists, beauticians, aestheticians, nail designers, etc.) do oftentimes have a comparable exposure to cosmetic glues while conducting diverse work tasks (nail treatments/nail art, make-up services including the application of artificial eyelashes, etc.).

2-Hydroxyethyl methacrylate (HEMA; substance identifiers: 2-hydroxyethyl methacrylate, 868-77-9, HEMA, methacrylic acid, 2-hydroxyethyl ester [6CI,8CI], methacrylic acid, ester with glycol [7CI], 2:1(methacryloxy)ethanol, 2-HEMA, 2-hydroxyethyl 2-methylprop-2-enoate, ethylene glycol methacrylate, ethylene glycol monomethacrylate, glycol methacrylate, glycol monomethacrylate, β-hydroxyethyl methacrylate) and ethyl cyanoacrylate (ECA; substance identifiers: ethyl cyanoacrylate, 7085-85-0, acrylic acid, 2-cyano-1-ethyl ester [6CI,7CI,8CI], 2-cyano-2-propenoic acid ethyl ester, 2-cyanoacrylic acid ethyl ester, ethyl 2-cyanoacrylate, ethyl 2-cyanoisopropenoate, ethyl α-cyanoacrylate).
this process, a set of full-text articles to be included in the systematic review was identified.

### 2.6 Data collection process and data items

Two reviewers independently extracted the data from studies meeting the inclusion criteria using a standardized, pre-piloted publication record form (PRF). In this review, only one PRF was used for clinical patch test studies because other study types did not apply. A third senior reviewer reviewed the extracted data and made final decisions in contradictory cases. The finalized PRF was preserved and is attached as supplemental material to this systematic review.

The following basic data were extracted: Publication ID, year of study execution, country of origin, study design, methods, study setting and population involved, information on basic characteristics of participants (eg, age, sex, ethnicity), number of participants, number of positive outcome(s), and funding source. Data on skin toxicity were sought for the outcome of skin sensitization/contact allergy in humans (eg, numbers tested, numbers positive, test methods).

### 2.7 Study risk of bias assessment, reporting bias assessment, and certainty assessment

Suitable criteria for assessing ROB and quality of evidence were applied. Two reviewers independently appraised studies meeting the inclusion criteria after full-text scrutiny without being blinded to the studies. Detailed criteria for the evaluation of quality and ROB were chosen according to Anon, Pluye et al., and Sterne et al.17-19

### 2.8 Effect measures

The risk ratio regarding skin sensitization/contact allergy for hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications versus comparators/controls, that is, people not working as hairdressers or beauticians, is provided by dividing contact allergy prevalence rates observed in hairdressers and beauticians by those observed in different comparator groups.

### 2.9 Synthesis methods

A substantial heterogeneity in both methodologies (even in the subcategories of ‘experimental’ and ‘clinical’ research) and outcomes was to be expected. Instead of a meta-analysis, we primarily conducted a narrative synthesis following guidance from the CRD.15 Summary tables present the main characteristics of the included studies, their findings, and their quality rating. Notwithstanding, for a subset of eligible studies, namely, those clinical patch test studies stratifying for hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications versus other “comparator” patients, a quantitative summary was feasible, in view of sufficiently uniform methodology and outcome definition. Here, graphical summaries as Forest plots with an assessment of heterogeneity (I²) are presented.

### 3 RESULTS

#### 3.1 Study selection and study characteristics

A flow diagram of the study selection is presented in Figure 2. The initial search yielded 579 study records. Following the removal of bibliographic duplicates, 163 records were left to be screened on the full-test level. Another eight references were found by manually searching references (ie, backward and forward snowballing). A number of studies appeared to meet the inclusion criteria at first,21-37 but they had to be omitted because they focused on a population that was inappropriate for this review. Case reports and case series were not included in the actual review, but compiled and extracted as supplemental information in case they were relevant in terms of including hairdressers and beauticians. We arrived at a final number of six papers after excluding publications that were extraneous to this review.

Characteristics of the included studies were recorded using a PRF (Table S1). All included studies (n = 6) were multicentric, retrospective patch test studies.48-53 Regarding the patch testing context, special series were tested in four studies,49-51,53 consecutive patients were tested in one study,52 and an epidemiological sample was tested in one study.48 The tested population comprised all patch tested patients (n = 5)48-51,53 or patients patch tested for occupational contact dermatitis only (n = 1).52

All of the six included studies reported on patch testing results for HEMA in hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications.48-53 Four of these studies also provided a comparator/control, that is, patch test results with other occupations or without occupational context.49-51,53 Because of their oftentimes comparable exposure to cosmetic glues while performing diverse work tasks (nail treatments/nail art, make-up services including the application of artificial eyelashes, etc.), occupational groups related to hairdressers within the cosmetic sector (manicurists, beauticians, aestheticicians, nail designers, etc.) were considered relevant for this systematic review.

The included studies were conducted in the European Union (n = 4), namely, in Germany (n = 1),49 Portugal (n = 1),51 Spain (n = 1),53 and Sweden (n = 1).50 Australia (n = 1),52 and the United States (n = 1).48 All studies report on a high share of female participants (>50% for all studies).58-53

All of the six studies included gave information on HEMA, but none offered information on ECA regarding the inclusion criteria/target population of hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications. Wetter et al. reported on patch test data from the Mayo Clinic, Rochester, Minnesota and Scottsdale, Arizona (2000-2007)
concerning allergens in personal care products, whereby 1.1% of 871 patients tested with ECA gave a positive test result. Warshaw et al. looked at patch test results of the North American Contact Dermatitis Group (2011-2012) and found that of 4230 people tested for ECA, 0.3% had a positive result. Warshaw et al. further conducted an analysis of patch test data from the North American Contact Dermatitis Group (2001-2016) regarding contact dermatitis associated with nail care products and reported that 6.9% of 175 people tested with ECA showed a positive result. Results regarding patch testing of ECA in hairdressers and beauticians are lacking.

3.2 | Risk of bias in studies, reporting biases, and certainty of evidence

Quality and ROB assessment (appropriate design, sampling, and sample; justification of methodology; justification/presentation of results) for the six studies included in this systematic review are presented in Table S2. All of the studies (n = 6) received high scores regarding appropriate design, sampling, and sample description; justification of methodology; and justification/presentation of results. As a result, we found the ROB to be low in all of the reports.

3.3 | Results of individual studies

Gatica-Ortega et al. analysed the files of patients diagnosed with allergic contact dermatitis caused by (meth)acrylates in long-lasting nail polish between January 2013 and June 2016 at four dermatological departments in Spain. As much as 39 of 40 (97.50%) hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications tested positive for HEMA, whereas of 2313 other people tested, only 4 (0.17%) had a positive patch test result.

Ramos et al. examined data from January 2006 to April 2013 of the Dermatology Department, Centro Hospitalar e Universitário de Coimbra, Coimbra, Portugal, with the aim to evaluate and correlate epidemiological and clinical parameters and positive patch test results against (meth)acrylates. As much as 20 of 35 (57.15%) tested hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications tested positive for HEMA patch test results; 10 of 87 (11.50%) other people tested had a positive HEMA patch test result.

Over a ten-year period, Teik-Jin Goon et al. looked into patients tested with the acrylate and nail acrylcs series at the Department of Occupational and Environmental Dermatology, Malmö University Hospital, Malmö, Sweden, to see if screening allergens could be
Of 13 included hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications, 8 (61.54%) were tested positive for HEMA, whereas of 24 others tested, only 1 (4.16%) showed a positive test result.50

Uter and Geier performed an analysis of patch test results with (meth)acrylates using patch test data of the Information Network of Departments of Dermatology from 2004 to 2013 to analyse the frequency of allergic contact dermatitis caused by (meth)acrylates used in artificial nails, comparing nail artists and consumers.

As much as 27 of 87 hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications, 8 (4.88%) showed positive patch test results for HEMA.

In the studies of Lyons et al.52 and Warshaw et al.48 a comparator/control was not available. Lyons et al. assessed patch testing results of hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications and trainees attending the Department of Occupational Dermatology Research and Education Centre, Carlton, Australia, from January 1993 to December 2010.52 Of 164 hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications, 8 (4.88%) showed positive patch test results for HEMA.52 Warshaw et al. conducted an analysis on patch test data from the North American Contact Dermatitis Group generated between 1994 and 2010 and found that of 57 hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications 15 (26.32%) tested positive for HEMA.49

Case reports on sensitization against HEMA are summarized in Table S3. In 2008, Andersen et al. reported on a 35-year-old female manicurist with 14 working years in Denmark with positive patch test results against HEMA.41 Kiec-Swierczynska et al. presented a case of a 32-year-old female manicurist with 3 working months in 2013 in Poland who was tested positive for HEMA as well as 2-hydroxypropyl methacrylate (HPMA).40 In 2019, Nakagawa et al. reported on a case of a 41-year-old female manicurist with 2 working years in Japan in 2019 showing a positive patch test result against HEMA and ethylene glycol dimethacrylate (EGDMA).39 In Finland, Pesonen et al. presented a case on a 34-year-old female cosmetician with over 8 working years who had a positive patch test reaction against HEMA.38

A summary of case series on sensitization against HEMA is displayed in Table S4. DeKoven et al. presented a case series in which six female nail technicians from Canada with an age ranging from 38 to 58 years tested positive for HEMA from 2015 to 2016.57 Le et al. reported on two female beauticians (23 and 25 years of age) and one female beauty therapist (20 years of age) in Australia showing positive patch test results for HEMA, methyl methacrylate (MMA), and EGDMA.60 Maio et al. described the cases of two female nail beauticians from Portugal in 2011 with ages of 35 and 50 years who presented positive patch test results for HEMA and HPMA.45 Minamoto on one female manicurist (35 years old) in Japan showing positive patch test results against HEMA, EGDMA, and triethylene glycol dimethacrylate in 13 female beauticians in Italy.43 Vázquez-Osorio et al. reported on two female manicurists aged 27 and 52 years in Spain showing positive patch test results for HEMA, EGDMA, and hydroxyethyl acrylate (HEA).42

There were no reports of active sensitization (ie, the patient being newly sensitized due to the patch test procedure) in the studies reviewed.

### 3.4 Results of syntheses

Figure 3 presents a forest plot depicting the risk of contact allergy to HEMA of hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications versus comparators/controls. In this meta-analysis, two studies were included.

| Author(s) and Year | Beautician pos. | Beautician neg. | Control pos. | Control neg. | Risk Ratio [95% CI] |
|-------------------|----------------|----------------|--------------|--------------|-------------------|
| Ramos et al. 2014 | 17             | 5              | 13           | 87           | 5.94 [3.41, 10.36] |
| Uter/Geier 2015  | 43             | 104            | 266          | 9676         | 10.93 [8.28, 14.44] |

RE Model (Q = 3.70, df = 1, p = 0.05; \(I^2 = 73.0\%\))

8.47 [4.70, 15.27]

0.25 1 4 16

Risk Ratio (log scale)

**Figure 3** Forest plot regarding the risk ratio of hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications versus others/nonhairdressers and nonbeauticians for 2-hydroxyethyl methacrylate (HEMA). The controls comprise other patch test patients patch tested with a special acrylate series, including consumers as well as occupationally exposed individuals in Ramos et al.53 and Uter and Geier49
which provided data about hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications as well as comparators/controls.\textsuperscript{49,51} The studies of Ramos et al.\textsuperscript{51} and Uter and Geier\textsuperscript{49} presented narrow confidence intervals indicating high precision. The pooled risk ratio was 8.47 (95% confidence interval 4.70-15.27). Thus, hairdressers and beauticians seem to have a ninefold increased risk of developing contact allergy to HEMA compared with controls who are not hairdressers or beauticians.

4 | DISCUSSION

In this unprecedented systematic review, aiming to compile and appraise evidence regarding skin toxicity of HEMA and ECA contained in cosmetic glues, it was found that hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications are subjected to a substantially higher risk of developing contact allergy against HEMA—representing a marker allergen within the group of (meth)acrylates—compared with other people not working as hairdressers or beauticians. All included studies provided clear evidence that occupational skin contact with cosmetic glues in the beauty sector might lead to elicitation of contact dermatitis; it further cannot be ruled out that a proportion of hairdressers and beauticians might even be sensitized within their occupational surroundings. This is especially true for hairdressers and beauticians who do not appropriately protect their hands by using gloves; however, even wearing gloves would not eliminate the substantial risk of sensitization because of the short break-through durations (<10 minutes)\textsuperscript{13,14} of acrylates for typical gloves used in the cosmetics sector.

It was deduced that occupational groups related to hairdressers within the cosmetic sector (manicurists, beauticians, aestheticians, nail designers, etc.) have a comparable exposure as hairdressers, because exposure to cosmetic glues while performing diverse work tasks (nail treatments/nail art, make-up services including the application of artificial eyelashes, etc.) is similar. An overview of selected European countries in which nail treatments and make-up services are part of the training as hairdresser shows that nail treatments are structurally integrated into the training as a hairdresser in Austria, Germany, Spain, and Switzerland; for make-up services this is the case in Austria, Denmark, and Germany (Table 2). This shows that a considerable proportion of hairdressers have a similar exposure to cosmetic glues used for conducting nail treatments and make-up services as in other occupations (eg, cosmeticians, make-up artists) and that the aforementioned consideration seems to be valid.

Even though published results specifically on hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications are very limited regarding sensitization to HEMA and non-existent in case of ECA, an overall substantial risk is to be expected from present data that cannot yet be fully quantified. The numerous case reports\textsuperscript{38-41} and case series\textsuperscript{27,42-47} on contact allergy against acrylates in those occupationally exposed in the beauty industry support this notion. Further, others acrylates such as MMA, EGDMA, triethylene glycol dimethacrylate (TREGDMA),

| Country       | Nail treatments\textsuperscript{a} | Make-up services\textsuperscript{b} |
|---------------|------------------------------------|-------------------------------------|
|               | Included?  | Structural integration within the training | Included? | Structural integration within the training |
| Austria       | Yes        | Framework curriculum for the apprenticeship as hairdresser—specialized classes/specialist knowledge and specialized internship | Yes        | Framework curriculum for the apprenticeship as hairdresser—specialized internship |
| Croatia       | No         | n/a | No | n/a |
| Denmark       | No         | n/a | Yes | Framework curriculum for the apprenticeship as hairdresser—make-up course |
| France        | No         | n/a | No | n/a |
| Germany       | Yes        | Framework curriculum for the apprenticeship as hairdresser—Learning area 10: hand care and nail design | Yes        | Framework curriculum for the apprenticeship as hairdresser—Learning area 11: using decorative cosmetics |
| Netherlands   | No         | n/a | No | n/a |
| Portugal      | No         | n/a | No | n/a |
| Spain         | Yes        | Framework curriculum for the apprenticeship as hairdresser—professional module 10 (includes manicure and pedicure) | No | n/a |
| Switzerland   | Yes        | Framework curriculum for the apprenticeship as hairdresser—elective manicure | No | n/a |
| United Kingdom| No         | n/a | No | n/a |

Abbreviation: n/a, not applicable.

\textsuperscript{a}Manicures, artificial nails/nail design, etc.

\textsuperscript{b}Day make-up, evening make-up, bridal make-up etc.
TABLE 3  Random sample of eyelash glues for temporary and permanent application of eyelash extensions sold within the European Union in local drugstores and/or perfumeries or in online shops along with their ingredients according to the International Nomenclature of Cosmetic Ingredients

| Product name                     | Manufacturer                                      | Ingredients                                                                 |
|----------------------------------|---------------------------------------------------|------------------------------------------------------------------------------|
| **Eyelash glues for temporary application (around 24 hours) of eyelash extensions** |                                                   |                                                                              |
| ARTDECO Eyelash Adhesive         | ARTDECO cosmetic GmbH, Karlsfeld, Germany          | Acrylates/ethylhexyl acrylate co-polymer, aqua (water), alcohol, propylene glycol, sodium benzoate |
| Adhesive Naomi Jon Tool Set      | Melody Lashes GmbH, Hamburg, Germany               | Acrylate co-polymer, aqua, hydroxypropylcellulose, CI 77491, fragrance      |
| Catrice Lash Glue 010            | cosnova GmbH, Sulzbach am Taunus, Germany         | Acrylates/ethylhexyl acrylate co-polymer, aqua (water), phenoxyethanol      |
| DUO Quick Set Adhesive Clear     | Bacodi GmbH, Wiesbaden, Germany                   | Acrylates/ethylhexyl acrylate co-polymer, alcohol denat, amp-acrylates co-polymer, phenoxyethanol, ethylhexylglycerin |
| DUO Quick Set Adhesive Dark      | Bacodi GmbH, Wiesbaden, Germany                   | Acrylates/ethylhexyl acrylate co-polymer, alcohol denat, amp-acrylates co-polymer, phenoxyethanol, ethylhexylglycerin, citric acid, sorbitol, sodium carbonate, cetareth-25, carbon black (CI 77266) |
| DUO Eyelash Adhesive Line It Lash It | Bacodi GmbH, Wiesbaden, Germany                | Water (aqua, Eau), ammonium acrylates co-polymer, glycerine, styrene/ acrylics/ammonium methacrylate co-polymer, 1,2-hexanediol, pentylene glycol, potassium sorbate, xanthan gum, butylene glycol, caprylyl glycol, c11-15 pareth-7, sodium laureth-12 sulfate, tetrasodium EDTA, sodium lauryl sulfate, disodium laur eth sulfosuccinate, phenoxyethanol, iron oxides (CI 77499) |
| Duo 2-in-1 Brush on Adhesive     | Ardell International, Inc., California, USA       | Acrylates/ethylhexyl acrylate, co-polymer, water (Eau, aqua), retinol, ascorbic acid, tocopherol, cetareth-25, propylene glycol, PEG 60 hydrogenated castor oil, glycerine, phenoxyethanol, iron oxides (CI 77499) |
| Essence Cosmetics Peel Off Lash Glue | cosnova GmbH, Sulzbach am Taunus, Germany    | Rubber latex, aqua (water), sodium dodecylbenzensulfonate, cellulose gum, dimethicone, ethylhexylglycerin, phenoxyethanol, sodium benzoate |
| Eylure 18H Lash Glue Latex Free Clear | Original Additions Beauty Products Ltd, Hayes, UK | Acrylates/ethylhexyl acrylate co-polymer, aqua/water, propylene glycol, *Bambusa vulgaris* (bamboo) extract, *Camellia sinensis* (tea) leaf extract, phenoxyethanol, ethylhexylglycerin, butylene glycol |
| Eylure 18H Lash Glue Latex Free Acrylic Black | Original Additions Beauty Products Ltd, Hayes, UK | Acrylates/ethylhexyl acrylate co-polymer, aqua/water, propylene glycol, *Bambusa vulgaris* (bamboo) extract, *Camellia sinensis* (tea) leaf extract, citric acid, sorbitol, ceteareth-25, sodium carbonate, phenoxyethanol, ethylhexylglycerin, butylene glycol, carbon black |
| Fesh! Eyelash Adhesive           | KTN Dr. Neuberger GmbH, Wiesbaden, Germany       | Acrylates/ethylhexyl acrylate co-polymer, aqua, propylene glycol, phenoxyethanol, ethylhexylglycerin |
| Hollybee Cosmetics Lash Glue     | Kafa Safari GmbH, Berlin, Germany                 | Water, cellulose gum, sodium dodecylbenzensulfonate, rubber latex, parfum, formalin solution, ammonium hydroxide |
| Huda Beauty Lash Glue            | HB USA Holdings, Inc., California, USA            | Rubber latex, sodium dodecylbenzensulfonate, cellulose gum, methylparaben, carbon black/CI 77266 |
| Kiss Everlasting Strip Eyelash Adhesive - Clear | Kiss Products Inc., Washington, USA        | Acrylates/ethylhexyl acrylate co-polymer, water (aqua), propylene glycol, butylene glycol, *Aloe barbadensis* leaf extract, phenoxyethanol, triethanolamine, carbomer, ethylhexylglycerin, fragrance (parfum), citral, citronellol, limonene, geraniol, hexyl cinnamal, linalool |
| Kiss Lash Glue Liner Black       | Kiss Products Inc., Washington, USA              | Water (aqua), acrylates/ethylhexyl, acrylate co-polymer, acrylate co-polymer, alcohol, 1,2-hexanediol, PEG 40, hydrogenated castor oil, sodium dehydroacetate |
| Kiss Lash Glue Liner Clear       | Kiss Products Inc., Washington, USA              | Water (aqua), acrylates/ethylhexyl, acrylate co-polymer, acrylate co-polymer, alcohol, 1,2-hexanediol, PEG 40, hydrogenated castor oil, sodium dehydroacetate |
| Melody Lashes Glued Adhesive     | Melody Lashes GmbH, Hamburg, Germany             | Rubber latex, acrylates co-polymer, aqua, cellulose gum, *Ricinus communis* (castor) seed oil, chamomilla recutita (*Matricaria*) flower oil |
| **Eyelash glues for permanent application (>1 week) of eyelash extensions** |                                                   |                                                                              |
| Ardell Lashtite Adhesive Clear   | Ardell International, Inc., California, USA       | Propylene glycol methyl ether acetate, nitrocellulose, SD Alcohol 40B, iron oxide |
| ARTDECO Adhesive for Permanent Lashes | ARTDECO cosmetic GmbH, Karlsfeld, Germany | Methoxyisopropyl acetate, alcohol denat., nitrocellulose |
HPMA, and HEA were reported to be the source of allergic contact dermatitis in people working in the beauty industry.\textsuperscript{39,40,42-46} This highlights the prevailing problem of cross-reactions, that is, sensitization induced by one acrylic compound extending to one or more other acrylics.\textsuperscript{37,56} As a result, many people sensitized to acrylics are multiply sensitized and, as a consequence, need to strictly avoid exposure to many other acrylics,\textsuperscript{56} with the notable exception of cyano- versus other acrylates/methacrylates which seem to not cross-react,\textsuperscript{57} although past studies provided conflicting clinical results.\textsuperscript{58,59}

In view of a lack of hairdresser-specific results on ECA, we examined a random sample of eyelash glues for temporary and permanent application of eyelash extensions, nail glues, and hair extension glues regarding their ingredients. Eyelash glues for temporary application of eyelash extensions mostly comprised ethylhexyl acrylate co-polymer and ammonium acrylates co-polymer (Table 3); in eyelash glues for permanent application of eyelash extensions, mostly ECA was found (Table 3). All of the nail glues within our random sample contained ECA (Table 4). Cases of ECA contact allergy in the context of false eyelashes reported by Shanmugam and Wilkinson as well as Sato et al. illustrate that cosmetic use of ECA might entail some risk of sensitization and a risk of elicitation in sensitized individuals.\textsuperscript{60,61}

Hair extension glues, such as eyelash glues for temporary application, have

| TABLE 3 | (Continued) |
| Product name | Manufacturer | Ingredients* |
| --- | --- | --- |
| DUO Individual Lash Adhesive Clear | Ardell International, Inc., California, USA | Water, rubber latex, cellulose gum, sodium dodecylbenzenesulfonate, ammonium hydroxide, fragrance, coumarin, geraniol, limonene, linalool, formaldehyde |
| Jolifin Lashes Eyelash Glue 1-2 sec, High Viscosity | Jolifin LJV GmbH, Babenhausen, Germany | Ethyl-2-cyanoacrylate, polyurethane, BHA, diisononyl adipate, sorbic acid, carbon black |
| Lankiz Lash Extension Glue | Hymax Company Ltd., London, UK | Cyanoacrylate, poly(methyl methacrylate), carbon black |
| Lavertu Glue 0.5-1 sec\textsuperscript{b} | Fresa Cosmetics B.V., Vught, the Netherlands | Ethyl cyanoacetate, cyanoacrylate, poly(methyl methacrylate), carbon black, poly isocyanate water, cyanoacrylate poly(methyl methacrylate) |
| Lavertu Glue 1-2 sec\textsuperscript{c} | Fresa Cosmetics B.V., Vught, the Netherlands | Ethyl cyanoacetate, cyanoacrylate, poly(methyl methacrylate), carbon black, poly isocyanate water, cyanoacrylate poly(methyl methacrylate) |
| Maxi Soft Glue | Eyemee the Beauty Co., Ltd., Seoul, Korea (south) | 2-Ethoxyethyl-2-cyanoacrylate, poly(methyl methacrylate), Cl 77866 |

Abbreviations: BHA, butylated hydroxyanisole; EDTA, ethylenediaminetetraacetic acid; PEG, polyethylene glycol.

*According to the International Nomenclature of Cosmetic Ingredients, as listed by the manufacturer.

\textsuperscript{b}Advertised longevity of 7 to 8 weeks.

\textsuperscript{c}Advertised longevity of 8 to 9 weeks.

| TABLE 4 | Random sample of nail glues sold within the European Union in local drugstores and/or perfumeries or in online shops along with their ingredients according to the International Nomenclature of Cosmetic Ingredients |
| Product name | Manufacturer | Ingredients* |
| --- | --- | --- |
| Ardell Nail Addict Professional Nail Glue | Ardell International, Inc., California, USA | Ethyl cyanoacrylate, poly(methyl methacrylate), BHA, red 7 (CI 15 850) |
| ARTDECO Nail Glue | ARTDECO cosmetic GmbH, Karlsfeld, Germany | Ethyl cyanoacrylate, poly(methyl methacrylate) |
| Essence Cosmetics Fix It! Nail Glue Violet | cosnova GmbH, Sulzbach am Taunus, Germany | Ethyl cyanoacrylate, poly(methyl methacrylate), water (water), alcohol |
| Elegant Touch Brush on Nail Glue | PDC brands, Hayes, UK | Ethyl cyanoacrylate, poly(methyl methacrylate), BHT |
| Elegant Touch Quick Dry Nail Glue | PDC brands, Hayes, UK | Ethyl cyanoacrylate, poly(methyl methacrylate), BHT, BHA |
| Kiss Maximum Speed Nail Glue | OBELIS S.A., Brussels, Belgium | Ethyl cyanoacrylate, poly(methyl methacrylate), BHA |
| Kiss Brush-on Nail Glue | OBELIS S.A., Brussels, Belgium | Ethyl cyanoacrylate, poly(methyl methacrylate), BHA, tetrahydrofuran, sulfur dioxide |
| Kiss Precision Nail Glue | Kiss Products Inc., Washington, USA | Ethyl cyanoacrylate, poly(methyl methacrylate), BHA, undecylenic acid |
| Kiss Maximum Speed Nail Glue Pink | Kiss Products Inc., Washington, USA | Ethyl cyanoacrylate, poly(methyl methacrylate), BHA, tetrahydrofuran, red 7 lake (CI 15850:1) |

Abbreviations: BHA, butylated hydroxyanisole; BHT, butylated hydroxytoluene.

*According to the International Nomenclature of Cosmetic Ingredients, as listed by the manufacturer.
also been shown to contain acrylates (Table 5). Although acrylate (co-) polymers are generally considered safe in terms of sensitization risk, residual monomers might pose a—yet unfathomed—risk at least for those already sensitized to the respective monomer from other sources. The sparse data situation on sensitization to specific acrylates in hairdressers and beauticians however points to an existing research gap which should be examined in further studies. Regarding inclusion of ECA in a hair cosmetic patch test series, only anecdotal evidence is yet available concerning actual sensitization and allergic contact dermatitis due to cosmetic products containing ECA. Hence, despite the considerable exposure, we would at present not recommend to add ECA to a hair cosmetic series, but suggest aimed testing in case of a—usually very clear—history.

Current articles by Romita et al. and Sterkens et al. report on the increasing use of (meth)acrylates in gel nail polishes—such as daylight curing ‘hybrid’ gel nail polish—and their role as sensitizers. This again stresses how (occupational) exposure is always shifting due to changing product compositions especially at work, posing a significant obstacle for completing a health risk assessment in the beauty industry. At this point it should be mentioned which can happen when cyanoacrylate-containing glues get on textiles/clothes in contact with skin.

By dint of the results of the present systematic review it seems appropriate that prevention strategies are developed for raising awareness in hairdressers and beauticians about the risk that handling cosmetic glues—especially without adequate protection—might entail. Such topical information (in any medial format) could be prepared under health pedagogical considerations and might be then presented within the framework of health education programs. This might also apply to other occupational fields for which relevant acrylate exposure has been evidenced in previous studies, such as dental personnel.

The German Social Accident Insurance (DGUV) has recognized the problem for dental personnel and initially launched information brochures about acrylate allergy and its prevention. These existing informational materials might serve as a point of entry for developing potential awareness campaigns and future training measures tailored to the needs of workers in occupational groups exposed to acrylates.

The present systematic review clearly shows that it is not appropriate to assess the risk of hairdressers and beauticians who handle cosmetic glues within their occupational surroundings regarding contact allergy to acrylates the same way as the risk of other people not working as hairdressers and beauticians such as consumers or clients. It was confirmed that the occupational risks associated with the use of cosmetic products are not sufficiently recognized by the regulations in force. The current SCCS opinion on the use of HEMA for nail cosmetics (SCCS/1592/17) seems not to be satisfactory for protecting hairdressers and beauticians who perform nail treatments and eyelash extension as well as hair extension applications.

The results of this paper point in favour of the notion that presumably an increase of the prevalence of sensitization against acrylates—such as HEMA—and consequently of contact dermatitis from cosmetic products containing acrylates might be expected in the future. The proven higher risk of hairdressers and beauticians regarding development of contact allergy against acrylates should lead to reconsidering current risk assessment. Only this way it will be possible to efficiently contribute to prevention of OSD in terms of HE in hairdressers and beauticians—according to the minimum standards set out in the position paper of the COST Action StanDerm (TD 1206)—to obviate personal suffering due to illness as well as high costs for the social insurance system and consequently the general population.

### Table 5: Random sample of hair (extension) glues sold within the European Union in local drugstores and/or perfumeries or in online shops along with their ingredients according to the International Nomenclature of Cosmetic Ingredients

| Product name         | Manufacturer | Ingredients*a |
|----------------------|--------------|---------------|
| Fidentia Bond Glue   | Fidentia professional line, Weil der Stadt, Germany | Xanthan gum, glycerine, water, acrylate co-polymer, nonphenol ethoxylate, colour white |
| Fidentia Bond Glue Pen| Fidentia professional line, Weil der Stadt, Germany | Xanthan gum, glycerine, water, acrylate co-polymer, nonphenol ethoxylate, colour white |
| Walker 1.4            | Walker Tape Co., West Jordan, USA | Purified water, hydrophilic acrylic co-polymer resins |
| Liquid Gold Extra Strong | Rapunzel AB, Umeå, Sweden | p-Chlorobenzonzoic fluoride, ethyl alcohol, methyl acetate, petroleum hydrocarbon resin, rosin ester, styrene-isoprene block co-polymer |

*aAccording to the International Nomenclature of Cosmetic Ingredients, as listed by the manufacturer.
AUTHOR CONTRIBUTIONS

Cara Symanzik: Conceptualization (equal); data curation (lead); formal analysis (lead); investigation (lead); methodology (equal); project administration (lead); visualization (lead); writing – original draft (lead); writing – review and editing (equal). Patricia Weiner: Conceptualization (equal); data curation (lead); investigation (equal); methodology (equal); project administration (lead); writing – review and editing (lead). Željka Babić: Conceptualization (equal); methodology (equal); writing – review and editing (supporting). Sarah Hallmann: Conceptualization (equal); methodology (equal); writing – review and editing (supporting). Martin S. Havmose: Conceptualization (equal); methodology (equal); writing – review and editing (supporting). Jeanne D. Johansen: Conceptualization (equal); methodology (equal); writing – review and editing (supporting). Sanja Kezic: Conceptualization (equal); methodology (equal); writing – review and editing (supporting). Marija Macan: Conceptualization (equal); methodology (equal); writing – review and editing (supporting). Jelena Macan: Conceptualization (equal); methodology (equal); writing – review and editing (supporting). Julia Strahlwald: Conceptualization (equal); methodology (equal); writing – review and editing (supporting). Rajka Turk: Conceptualization (equal); methodology (equal); writing – review and editing (supporting). Henk F. van der Molen: Conceptualization (equal); methodology (equal); writing – review and editing (supporting). Wolfgang Uter: Conceptualization (equal); methodology (equal); writing – review and editing (supporting).

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