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Use of protective gloves by hairdressers: A review of efficacy and potential adverse effects

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Abstract

Occupational hand eczema is common among hairdressers, and protective gloves are important in limiting exposure to irritants and allergens. Various glove types may differ in their protective ability, and their use may lead to hand eczema due to skin irritancy and allergy. MEDLINE was searched for studies investigating permeation of gloves to irritants and allergens used in the hairdressing trade, as well as adverse effects of glove use affecting hairdressers. Forty-four studies were identified; nine reported on permeation. Of those, two in vitro studies found nitrile rubber (NR) gloves to give the best protection when handling hair dyes. Polyethylene (PE) gloves had the lowest reported break-through time. The prevalence of sensitization to rubber materials in European hairdressers was as follows: thiuram mix, median 2.5% (range 0%-8.2%), weighted average 3.0% (95% confidence interval [CI] 3.0%-3.1%); mercapto mix, median 0.4% (range 0%-3.3%), weighted average 0.5% (95% CI 0.47%-0.50%), mercaptobenzothiazole, median 0.6% (range 0%-6.6%), weighted average 0.7% (95% CI 0.6%-0.7%), NRL-type I allergy, median 1.3% (range 1%-16.4%), weighted average 4.0% (95% CI 3.6%-4.5%). In conclusion, NR gloves provide the best skin protection for hairdressers, although natural rubber latex (NRL) and polyvinylchloride (PVC) gloves may be sufficient in most cases. PE gloves are not recommended. Synthetic rubber gloves with low or no levels of accelerators are preferred.

KEYWORDS

adverse effects, gloves, hairdressers, permeation, rubber, sensitization

1 | INTRODUCTION

Occupational hand eczema is a multifactorial disease caused by exposure to irritants and/or allergens. Hairdressers are among professions with the highest risk of developing hand eczema and the incidence rate ratio has been estimated to be 1.7-2.5, compared to the general population.^{1,2} Due to excessive wet-work and frequent contact with allergens in hair dyes, shampoos, permanent wave solutions, and bleaching and styling products, hand eczema tends to debut early in the career, with many hairdressers having to leave the trade prematurely.³

Evidence-based skin protection programs have been developed as primary prevention of occupational hand eczema. A key feature of

such program is promotion of the correct use of protective gloves, that is, safe application and use when appropriate.⁴ Intervention studies on hairdressing apprentices in Denmark and Germany have shown such program to be effective, leading to an increase in adherence to glove use and a reduction in the prevalence of hand eczema.^{5,6}

Gloves used by hairdressers are typically made from either natural rubber latex (NRL), synthetic rubber, or plastic polymeric materials.⁷ Despite this categorization by material, gloves are not a homogenous entity, and permeability depends on composition of the material, thickness, and quality control—all features that may vary by manufacturer.⁸ Because the glove type is not a predictor of the protective ability, hairdressers may in theory choose a glove that is not able to be

protective for the intended exposure.⁸ To evaluate the threshold of permeability, permeation studies have been done in vitro and in vivo.

Although gloves are beneficial in the primary prevention of occupational dermatitis, the use of gloves is in itself a risk factor for contact dermatitis of the hands. The occlusive effect contributes to wet-work exposure, that alongside friction can irritate the skin, and natural and synthetic rubber glove use may sensitize the user to latex proteins or rubber accelerators.

We reviewed the available literature on permeation of protective gloves to irritants and allergens in the hairdressing trade. We also reviewed the adverse effects of gloves when used by hairdressers, that is, sensitization to rubber materials and occlusion, as well as which glove types are most commonly used.

2 | METHOD

Eligibility criteria

Inclusion criteria were published studies, written in English, examining permeation of gloves to irritants and/or allergens used in the hairdressing trade. In addition, studies on adverse effects of gloves affecting hairdressers and types of gloves used were included.

Literature search

Literature in the MEDLINE database was sought from inception to December 2019. A search in PubMed was performed with the following free-text terms: hairdress* AND (glove* OR nitrile OR latex OR PVC OR vinyl OR polyethylene OR rubber OR carbamates OR thiuram OR patch test). Studies that by title and abstract clearly did not meet the inclusion criteria were excluded. The remaining studies were examined for eligibility by assessing the full-text. Studies identified by scrutinising reference lists underwent the same assessment as studies found in MEDLINE.

For studies reporting on the prevalence of sensitization in absolute numbers, the proportion of the study population was calculated in percent. A weighted average with 95% confidence intervals was calculated for studies reporting on sensitization to rubber compounds in the European baseline series, that is, thiuram mix, mercapto mix, and mercaptobenzothiazole. In intervention studies, data from the control group was collected. Data analysis was performed in IBM SPSS Statistics version 25.

3 | RESULTS

3.1 | Study selection

The initial search in MEDLINE yielded 240 relevant titles. Screening by title and abstract resulted in 89 studies that were obtained for full-

text review. A total of 44 studies were included of which three were identified by scrutinizing references (Figure 1).

3.2 | Permeation of glove materials

Studies on permeation are typically done in vitro in a two-compartment setup and reported as a break-through time (BT) and steady state permeation rate (SSPR). The BT is often reported as the cumulative BT (lag-BT), which is the intercept of the SSPR with the x-axis denoting units of time. In vivo studies are designed either as a patch test setup where an allergen is placed upon glove material, or by observation of work scenarios and sequentially measuring external contamination or systemic uptake. Three in vitro studies measured permeation of hair dyes in either ethanol or buffer solutions, with or without hydrogen peroxide (Tables 1 and S1).^{9–11}

Disposable NRL gloves have been tested against *p*-phenylenediamine (PPD), toluene-2,5-diamine sulfate (TDS), resorcinol, and aminophenol isomers. The lowest recorded BT was seen for *o*-aminophenol at 60 minutes, PPD at 90 minutes, and *m*-aminophenol at 200 minutes in ethanol solutions.¹¹ BT increased to >240 min for PPD and aminophenol isomers when mixed with hydrogen peroxide. For resorcinol, an increase in lag-BT from 155.4 to 158.2 minutes was seen for glove material pretreated with hydrogen peroxide.¹⁰ The remaining tests with resorcinol and TDS in buffer solutions had lag-BTs >240 minutes.⁹

Disposable polyvinylchloride (PVC) gloves have been tested with the same chemicals as the NRL gloves. The lowest recorded BT was seen for *o*-aminophenol and PPD, both at 40 minutes in ethanol solutions.¹¹ As for the NRL gloves, BT increased to >240 minutes for PPD and aminophenol isomers when tests were performed in a hydrogen peroxide solution. In contrast, permeation of resorcinol was seen to decrease slightly from a lag-BT of 99.3 to 89 minutes in glove material pretreated with hydrogen peroxide.¹⁰ Thus, PVC gloves provided less protection than NRL gloves to resorcinol, aminophenol isomers, and PPD, but equal effects in relation to TDS.

Disposable nitrile rubber (NR) gloves have been tested with resorcinol, PPD, and TDS, but not aminophenol isomers. Lag-BTs ranged from 183 to 222.7 minutes for resorcinol in buffer solution, and no break-through was detected for PPD and TDS at 240 minutes in ethanol solution. No significant change in the lag-BT for resorcinol was noted when the glove was pretreated with hydrogen peroxide. Thus, NR and NRL gloves gave equal protection to PPD and TDS, with the exception of resorcinol, where ambiguous results were found.^{9,10}

Disposable PE and reusable neoprene gloves were examined in one study each. The neoprene glove had the highest recorded BT at >480 minutes to PPD and aminophenol isomers, whereas the PE glove had the lowest recorded lag-BT of 32 minutes to PPD.^{9,11} This span in BT/lag-BT illustrates the importance of glove thickness to permeation, as the neoprene glove was 31 times thicker than the PE glove (0.62 and 0.02 mm, respectively). Furthermore, the neoprene glove was four to seven times thicker than the NRL and PVC glove (0.14 and 0.09 mm, respectively) it was compared to, whereas the PE

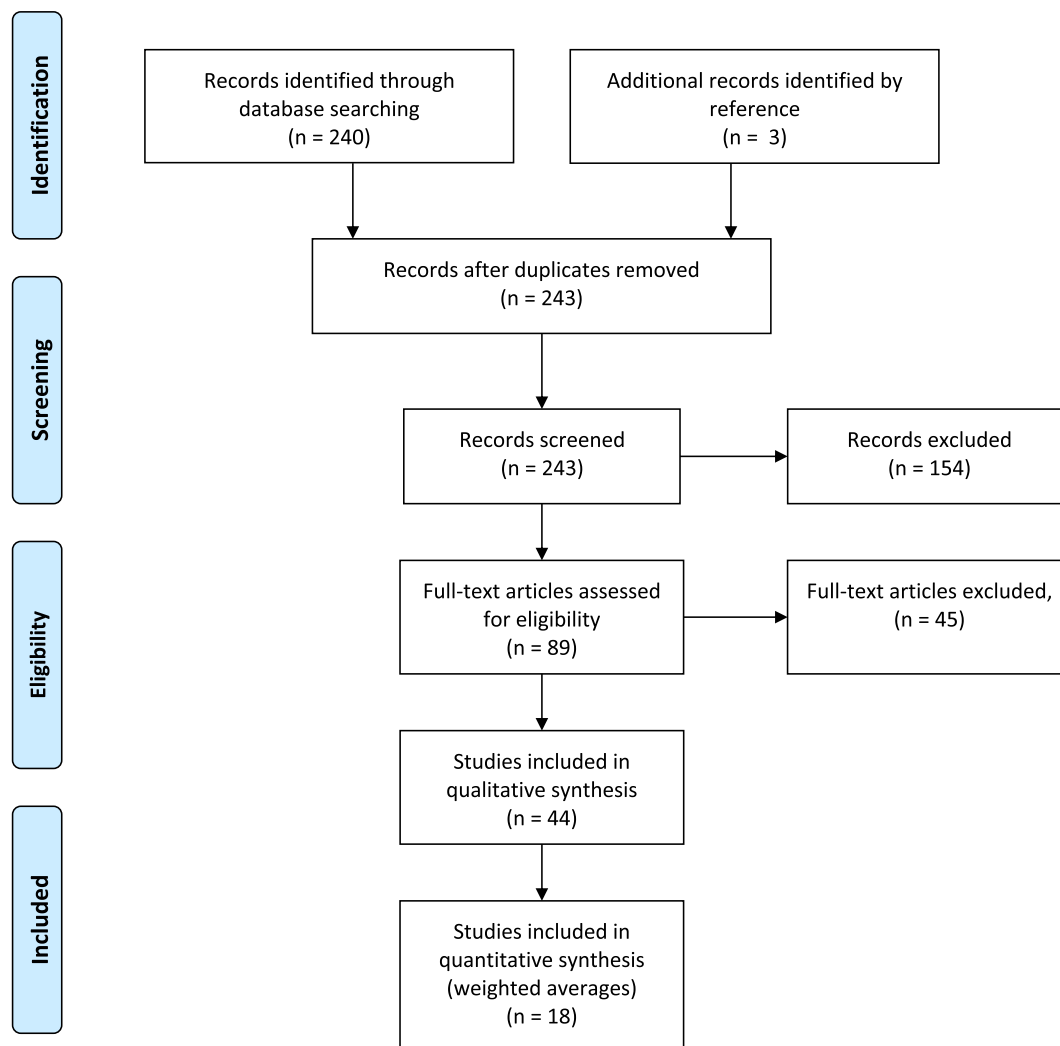


FIGURE 1 Flow diagram of literature search

glove was 6-10 times thinner than the NRL, PVC, and NR (0.20, 0.12 and 0.11 mm, respectively) gloves it was tested against.^{9,11} The ambiguous results of permeation of NR and NRL gloves with resorcinol were explained by the authors to be due to glove thickness of the NRL glove, making it perform better in the first study and worse in the latter.^{9,10} Although the relationship between permeation and thickness might seem as reciprocal entities, the importance of the composition of the material was reflected in the study by Lind et al, where the NR glove had a higher lag-BT to resorcinol than the PVC and NRL gloves (0.10, 0.12, and 0.17 mm, respectively), despite being 1.2 and 1.7 times thinner.¹⁰

Although permeation assessed in vitro gives a good indication of the protective capability of a glove, in vivo studies have indicated that precautions are needed in previously sensitized individuals. Despite the lowest estimated breakthrough of PPD ranging from 32 to 90 minutes for PE gloves, PVC gloves, and NRL gloves, a patch test study of PPD-sensitized individuals involving exposure to PPD, through NRL, PVC, and PE glove materials, showed eczematous reactions at 15 minutes of exposure for all three glove types. No reactions were seen for NR

gloves in the 60 minute study period.¹² Of note, the tested gloves were all thinner (range 0.03-0.04 mm) compared to the gloves tested in vitro. A similar study with glyceryl monothioglycolate (GMTG)-sensitized individuals with GMTG through vinyl glove material showed positive patch test reactions at day 2 and 3, although the reading time was too long to reflect glove use in a real working scenario.¹³ According to the ASTM F 39 standard and the European Standard EN 374-3:2003, break through is considered to have happened if permeation reaches $0.25 \mu\text{g}/\text{cm}^2$ and $1 \mu\text{g}/\text{cm}^2/\text{min}$, respectively. The EN 374 detection limit was, according to Lind et al, insufficient to require their recorded lag-BTs to be reported.⁹ This problem is potentially illustrated in the patch test study of PPD-sensitized individuals, where the reactions to PPD must be assumed to stem from very low permeated amounts in a short period.

Intervention studies investigating the protective effect of gloves to hair dyes have further bridged the in vitro findings with real-work scenarios. Geens et al found that adequate use of NR gloves reduced the systemic exposure to TDS, but not to PPD.¹⁴ The inability of gloves to protect against PPD was also seen in a study investigating the relationship between self-reported glove and systemic exposure to TDS and

TABLE 1 Range of reported breakthrough time (minutes) in relation to glove material

	<i>p</i> -Phenylenediamine		Toluene-2,5-diamine		Resorcinol		<i>p</i> -aminophenol		<i>m</i> -aminophenol		<i>o</i> -aminophenol	
Glove material	Ethanol/ buffer	Hydrogen peroxide (12%)	Ethanol/ buffer	Hydrogen peroxide (NA)	Ethanol/buffer	Hydrogen peroxide (30%)	Ethanol/ buffer	Hydrogen peroxide (12%)	Ethanol/ buffer	Hydrogen peroxide (12%)	Ethanol/ buffer	Hydrogen peroxide (12%)
NRL ^b (0.14–0.20) ^c	BT 90–120	BT > 240					BT > 240	BT > 240	BT 200 to >240	BT > 240	BT 60–90	BT > 240
	Lag- BT > 240		Lag- BT > 240		Lag-BT 155.4 to >240	Lag BT 158.2						
NR ^b (0.10–0.11) ^c	Lag- BT > 240		Lag- BT > 240		Lag-BT 183– 222.7	Lag-BT 221.1						
PVC ^b (0.09–0.12) ^c	BT 40–60	BT > 240					BT 110– 170	BT > 240	BT 80–120	BT > 240	BT 40– 100	BT > 240
	Lag-BT 86		Lag- BT > 240		Lag-BT 90–99.3	Lag-BT 89						
PE ^b (0.02) ^c	Lag-BT 32		Lag- BT > 240		Lag-BT 119							
Neoprene (0.62) ^c	BT > 480	BT > 480					BT > 480	BT > 480	BT > 480	BT > 480	BT > 480	BT > 480

Note: BT is the elapsed time (min) from exposure of a chemical to its presence on the other side of the material. Lag-BT is the intercept of the steady-state permeation rate with the x-axis denoting units of time (min).

Abbreviations: BT, breakthrough time; lag-BT, cumulative break-through; NRL, natural rubber latex; NR, nitrile rubber; PVC, polyvinylchloride; PE, polyethylene; SD, standard deviation.

^aGlove material pretreated with 30% hydrogen peroxide.

^b Disposable gloves (when specified).

^cRange of average glove thickness in mm.

TABLE 2 Potential reasons for developing hand eczema from glove use

Sensitization and elicitation of allergic contact dermatitis from glove materials ⁵²
<i>Increased exposure</i> to allergens from internal contamination when gloves are used inadequately: Reusing disposable gloves and turning them inside out. ^{5,7,17}
Washing disposable gloves and dusting them with talcum powder before turning them inside out. ^{14,27}
Lack knowledge on how to remove gloves correctly, consequently contaminating the hands. ¹⁹
Reduction in efficacy due to artificial fingernails and rings bridging the fingers. ^{7,19}
Contamination of the forearms due to too short gloves. ¹⁵
Transient impairment of the skin barrier. ⁵⁹
Incorrect glove size. ⁴⁷

PPD.¹⁵ Systemic exposure has been hypothesized to stem from inadequate glove use or differences in absorption or toxicokinetics^{14–16} By using a hand-rinse method, Lind et al studied contamination of the hands with PPD, TDS, and resorcinol, and found no statistically significant difference when comparing glove users and nonglove users. Again, this was thought to stem from improper glove use.¹⁷ Conversely, Hueber-Becker et al found that glove use gave sufficient protection against systemic exposure to PPD. However, the participants wore coveralls in addition to gloves and worked on artificial training heads in a controlled working environment.¹⁸ In summary, the findings of these in vivo studies illustrates the difficulties in this experimental setup and most likely a problem of inadequate glove use.

3.3 | Incorrect handling of gloves

In 2016, Geens et al. observed hairdressers wash disposable gloves and apply talcum to the exterior surface, before turning them inside out for reuse.¹⁴ Oreskov et al observed hairdressers while performing a hair wash with gloves, showing a lack of knowledge on how to handle gloves appropriately, leading to contamination of the hands. A substantial number of the participants had long nails and wore jewelry, making correct glove use difficult.¹⁹ In 2012 in Denmark, self-reported data from hairdressers showed that 58.6%–59.6% had reused gloves and 8% turned gloves inside out before reusing them.^{5,7} Nixon et al reported that 4.2% of Australian hairdressers and apprentices experienced problems due to incorrect size of the gloves. Too small gloves could in theory affect permeation by stretching the glove material, whereas too large gloves do not properly fit at the wrist.

3.4 | Sensitization to gloves materials

Thiuram mix was the most commonly studied compound with patch test data from 14 studies (Table S2).^{20–39} Among hairdressers in

Europe, the median prevalence of sensitization to thiuram mix was 2.5%, ranging from 0%–8.2%, with the weighted average being 3.0% (95% confidence interval [CI] 3.0%–3.1%). Mercapto mix and mercaptobenzothiazole were the second most commonly studied compounds with patch test data from eight studies each. For hairdressers in Europe, the median prevalence of sensitization to mercapto mix was 0.4%, ranging from 0%–3.3%, and a weighted average of 0.5% (95% CI 0.47%–0.5%). For mercaptobenzothiazole the median was 0.6%, ranging from 0%–6.6%, with a weighted average of 0.7 (95% CI 0.6%–0.7%). Sensitization to carba mix ranged from 0%–2.8%, with the highest prevalence in hairdressers diagnosed with hand dermatitis in Greece.^{13,40,41} The median prevalence of type-I allergy to NRL in European hairdressers was 1.3% (range 1%–16.4%) and a weighted average 4.0% (95% CI 3.6%–4.5%). Among patients with occupational contact urticaria, hairdressers with positive prick test to latex glove material accounted for 6%–9% of the study population.^{42,43}

3.5 | Contribution of occlusion to wet-work

The mean daily glove use ranged from 2.9–3.4 hours/day in hairdressers in Italy.^{44,45} In Denmark, glove use >2 hours/day was estimated to occur in 38.1%–40.9% of hairdressers, making it a significant contribution to wet-work (Table S3).^{5,7} This was further illustrated by Kralj et al who, by observing 106 8-hour shifts, estimated 18% of daily wet-work to be a consequence of wearing gloves.⁴⁶ In addition to being a risk factor for irritant contact dermatitis, the occlusive effect has been reported to be uncomfortable by 30% of hairdressers in Australia, complaining that gloves make the hands sweat.⁴⁷

3.6 | Types of gloves used by hairdressers

NRL was the most commonly used material, ranging from 18%–68.7% in Europe (Table S4).^{7,17,44,48–50} The highest reported use was in Greece in 2019. In comparison, only 34.9% of Danish hairdressers reported to use NRL gloves in 2012. Use of synthetic rubber or nitrile gloves ranged from 3%–45.3%, increasing across time.^{7,17,44,47} Use of PVC gloves ranged from 12%–35.6%, with the highest prevalence of use in Denmark in 2012.^{7,17,44,47,50} The use of PE ranged from 0%–46%, with a trend of decreasing use.^{7,17,44,50} Thus, NRL and NR gloves seem to be the most commonly used gloves by hairdressers in Europe, followed by PVC and PE gloves.

4 | DISCUSSION

This review showed that protective gloves in general are suited for protection against hair dyes. NR gloves provided the best overall protection and PE gloves the worst, having the shortest recorded lag-BT of 32minutes. For NR gloves, a thickness of 0.04mm gloves seems to be safe for at least 60minutes to PPD, whereas a thickness of 0.1mm.

is sufficient for resorcinol, PPD, and TDS for a minimum of 180 minutes. Disposable gloves should not be reused; the varying breakthrough times emphasize the importance of compliance with this guideline. In addition, the patch test study with PPD through glove material indicates that permeation might still occur despite this not being detected in the *in vitro* studies. Thus, precautions are needed in hairdressers sensitized to PPD. The *in vivo* patch test study was done with thinner gloves than in the *in vitro* studies. This may have reduced breakthrough time despite the gloves being made of the same materials as used *in vitro*. A standard for protective gloves for hairdressers is needed to add transparency to permeation of various gloves. The current variation in thickness and composition between different manufacturers makes it difficult to navigate the market of protective gloves. Of note, Lind et al found that lag-BTs currently need not to be reported according to the EN 374, emphasizing the need for stricter regulations.⁹

Thoughts on an ideal glove for hairdressers have previously been expressed, describing qualities such as being inexpensive, easy to apply, nonirritating, and impermeable to penetration.⁴⁷ It is worth adding the feature of being nonsensitizing, as commonly used glove materials are NRL and synthetic rubber, both known to contain sensitizers. NRL can cause immediate hypersensitivity reactions, and both natural and synthetic rubber gloves contain allergenic rubber accelerators. Commonly used accelerators are tested for in the European Baseline Series with thiuram mix 1% pet., mercapto mix 1% pet., and mercaptobenzothiazole 2% pet. The overall prevalence of sensitization in patch-tested patients is, according to European Surveillance System on Contact Allergies (ESSCA), 1.9% (95% CI 1.8%-2.1%) to thiuram mix, 0.7% (95% CI 0.5%-0.9%) to mercapto mix, and 0.6% (95% CI 0.5%-0.7%) to mercaptobenzothiazole.⁵¹ We found the weighted average of sensitization to these compounds in hairdressers to be 3.0% (95% CI 3.0%-3.1%), 0.5% (95% CI 0.47%-0.5%), and 0.7% (95% CI -0.6%-0.7%), respectively. Thus, hairdressers were more often sensitized to thiurams compared to the average patch-tested population. When comparing hairdressers to ESSCA data from clinics specialized in occupational dermatology, the difference becomes less noticeable with sensitization to thiuram mix being 2.9 (95% CI 2.2%-3.6%), mercapto mix 1% pet. 0.8 (95% CI 0.4%-1.2%), and mercaptobenzothiazole 0.7% (95% CI 0.6%-0.7%), showing sensitization of hairdressers to thiurams on par with other occupations.

The association of thiuram sensitization and contact dermatitis has been shown to be higher in hairdressers, compared to white-collar workers.⁵² To address the need for secondary prevention of rubber allergy, glove manufacturers have begun producing gloves without rubber accelerators.⁸ Vulcanization, the process of cross-linking rubber isomer with sulfur, is usually done by adding rubber accelerators to speed up the process of covalent bonding. The rubber accelerators are not integrated into the polymeric network and are therefore at risk of leaching from rubber products. Accelerator-free gloves are manufactured by using base materials, such as carboxylated nitrile rubber or synthetic isoprene and other vulcanization agents, for example, zinc oxide or ultraviolet light.⁵³ Accelerator-free gloves seem to

be able to conform with the EN 374-3 for chemical hazards, but there are currently no published studies on the preventive effect of accelerator-free gloves in hairdressers.⁵⁴ For conventional rubber gloves, a standard on the leachable amounts of rubber accelerators is needed to reduce the risk of sensitization to these compounds.

We found the most commonly used glove material to be NRL, followed by synthetic rubber and plastic. The popularity of NRL gloves among hairdressers is similar to the choice of NRL gloves in health care professionals. The use of NRL gloves increased by 87.9% from 1986 to 2007 in German Hospitals. Despite this, a reduction in the prevalence of NRL-induced contact urticaria in health care professionals was seen in the same period, with approximately 2% being reactive in 2012.⁵⁵ This was thought to be due to a shift toward nonpowdered NRL gloves. The weighted average of the prevalence of NRL sensitization in hairdressers was 4% (95% CI 3.6%-4.5%). The higher prevalence in hairdressers, compared to health care professionals, may be due to studies with highly selected study populations included in this review. One study investigated regular users of rubber gloves and another hairdressers reporting symptoms in response to use of NRL gloves.^{45,56} Another explanation is the possible use of powdered NRL gloves by hairdressers, increasing their risk of allergy. Although NRL gloves provide good protection against hairdressing chemicals, patients diagnosed with a type-I allergy to NRL are at risk of anaphylactic reactions on exposure to NRL. With NR gloves providing better protection than NRL gloves and PVC gloves sufficient protection in most scenarios, the use of non-NRL gloves seems a rational choice.

Daily glove use is generally considered a contribution to daily wet-work.⁵⁷ Despite this, gloves have been shown to potentially reduce the risk of skin changes compared to actual wet-work.⁵⁸ More recently, it has been documented that prolonged glove use with clean hands does not affect the skin negatively.^{59,60} The working environment of hairdressers makes frequent glove change necessary and the known difficulties in handling gloves correctly pose a risk of contaminating the hands of hairdressers. As a result, allergens may become trapped within the gloves and lead to increased exposure. Because protective gloves seem to be relatively safe in terms of occlusion, the main concern is the prevention of internal contamination by the handling of gloves correctly and knowledge of permeation (Table 2).

In conclusion, NR gloves provide the best protection against oxidative hair dyes for hairdressers. NRL and PVC gloves may be sufficient in many cases. However, this may depend on the thickness of the material. Taking the risk of sensitization to rubber materials into account, synthetic rubber with low or no levels of accelerators is preferred. New standards should be developed that make it transparent for the hairdressers not only whether the glove is resistant to hairdressing chemicals, but also easy to choose a glove with no or reduced risk of contact allergy.

AUTHOR CONTRIBUTIONS

Martin Havmose: Jacob Thyssen: Formal analysis; writing-review and editing. **Claus Zachariae:** Formal analysis; writing-review and editing. **Jeanne Duus Johansen:** Conceptualization; formal analysis; writing-review and editing.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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Online supplementary material

Supplementary table 1: Studies on permeation of gloves with allergens used in the hairdressing trade

Author	Year	Country	Hairdressers (n)	Age (Years)	Glove (mean thickness in mm with SD)	Allergen	Study design 1	Study design 2	In vivo sample	Comments on break-through time	Comments on steady state permeation rate	Other
Geens et al. ¹⁴	2016	Belgium	11	Mean 31	NR [†] (NA)	PPD TDS	In vivo	Non-randomized, uncontrolled before and after study. Intervention with instructions and NR gloves. Latex were gloves available before intervention.	Urinalysis	NA	NA	Adequate use of nitrile gloves reduced systemic exposure of hairdressers to PTD. No effect on PPD was observed.
Lind et al. ¹⁰	2014	Sweden	NA	NA	NRL [†] (0.17 ± 0.008) NR [†] (0.10 ± 0.005) and PVC [†] (0.12 ± 0.005)	Resorcinol with and without hydrogen peroxide	In vitro	Permeation test with a two-compartment cell method.	NA	The cumulative breakthrough time was >1hour but <4 hours for all tested gloves. Pretreatment of PVC gloves with hydrogen peroxide resulted in a slightly decreased breakthrough time. No change on NR gloves.	Pretreatment of NRL gloves with hydrogen peroxide decreased the permeation rate. No change on NR gloves was observed.	Treatment with hydrogen peroxide had a minor effect on permeation. NR gloves provided the best protection. Taking the risk of allergy into account, PVC are recommended. PVC gloves may not be used >1 hour. Disposable gloves should never be reused.
Antelmi et al. ¹²	2014	Sweden	8	Median 37	NRL (0.038) NR (0.035-0.040) PVC (0.034-0.037) and PE (0.029)	PPD mixed with hydrogen peroxide	In vivo	Provocation of 8 PPD-sensitized individuals with PPD through glove material.	Patch test	Ecematous reactions where observed for the NRL, PVC and PE gloves within 15 minutes with increasing prevalence at 30 min and 60 min.	NA	Nitrile gloves gave best protection. Many gloves used by hairdressers are unsuitable for protection against the risk of elicitation of allergic contact dermatitis caused by PPD.
Gube et al. ¹⁵	2011	Germany	52	Median 31	NA	PPD and TDS	In vivo	Case-control. Self-reported exposure to hair dyes and use of gloves	Urinalysis	NA	NA	No correlation between concentration of urinary diamines and the use of protective gloves
Lee et al. ¹¹	2009	Taiwan	NA	NA	NRL [†] (0.1402 ± 0.0065) NA PVC [†] (0.0897 ± 0.0038)	PPD, m-, o- and p-amino-phenol in	In vitro	American Society for Testing and Materials type permeation cell	NA	peroxide did not accelerate break through	Higher for PVC than NRL gloves	Disposable NRL and PVC gloves should not be used repeatedly.

Tabella formattata

					Neoprene (0.6211 ± 0.0080)	ethanol and hydrogen peroxide solutions						
Lind et al. ⁹	2007	Sweden	NA	NA	NRL [†] (0.20 ± 0.008) -NR [†] (0.11 ± 0.005) -PVC [†] (0.12 ± 0.008) -and PE [†] (0.02 ± 0.01)	PPD, TDS and Resorcinol	In vitro	American Society for Testing and Materials type permeation cell	NA	For the NRL glove the permeated amounts were below the analytical levels. The NR glove was permeated only by RES. The PE glove where the thinnest glove and had the lowest BT at 32 min.	The PE glove, despite being the thinnest glove, had the lowest SSPR.	If properly used all tested gloves gave considerable protection against permeation of PPD, TDS and RES.
Hueber-Becker et al. ¹⁸	2006	Germany	18	Mean 39	Not mentioned. Participants wore coveralls in addition to gloves.	C14-PPD	In vivo	Observation of hair dyeing on artificial training heads. Gloves worn during hair dying and washing/shampooing	Hand rinses and urinalysis	NA	NA	Occupational use of hair dyes produces negligible local and systemic exposure to PPD.
Lind et al. ¹⁷	2005	Sweden	33 (17 used gloves)	Mean 37	NRL (NA); Vinyl (NA) -PE (NA) -NR (NA)	PPD, TDS and resorcinol	In vivo	Hairdressers in salons	Hand rinse	NA	NA	Glove use where improper and insufficient to prevent exposure to hair dyes.
Guerra et al. ¹³	1992	Italy	8	NA	PVC (NA)	GMTG	In vivo	8 patients GMTG- sensitized individuals were patch tested with GMTG through glove material.	Patch test			Three were positive at 2 and 3 days.

[†] Disposable gloves (when specified)

Abbreviations: GMTG, glyceryl monothioglycolate; NA, not applicable; NRL, natural rubber latex; NR, nitrile rubber; PVC, polyvinylchloride; PE, polyethylene; PPD, p-phenylenediamine; TDS, toluene-2,5-diaminesulfate; RES, resorcinol; SD, standard deviation

Formattato: Tipo di carattere: Non Grassetto

Formattato: Tipo di carattere: Non Grassetto

Supplementary table 2. Prevalence of sensitization (%) to glove materials among hairdressers

[illegible]

Guo et al. ⁵⁷	1994	Taiwan	Random sample from salons	98	Median 19		0			1		0	1	
Van der Walle et al. ⁵⁸	1994	Netherlands	Investigated at center for occupational dermatology	103	Most common age group 16-20		1							
Sutthipisal et al. ⁵⁹	1993	England	Hand-eczema, non-atopics	66	Most common age group 15-18		3.5				0			
Guerra et al. ¹³	1992	Italy	Hairdressers with contact dermatitis	302	Mean 24.6		1.3					0.7		
Nethercott et al. ⁶⁰	1986	Canada	Hand dermatitis	18	Mean 24.5						5.6			
Lynde et al.	1982	Canada	NA	66	Most common age group 16-25		0				0			

Abbreviations: NA, not applicable; ZDEC, zinc diethyldithiocarbamate; TMTD, tetramethylthiuram disulfide; TMTM, tetramethylthiuram monosulfide; TETD, tetraethylthiuram disulfide/disulfiram

Supplementary table 3: Glove use as a contribution to wet-work

Author	Year	Country	Hairdressers/apprentices (n)	Age	Glove use/day	Other
Piapan et al. ²⁴	2019	Italy	64	Mean 42.4	Mean 2.9 hours/day	
Lysdal et al. ⁷	2012	Denmark	5234	Mean 36.4	40.9% wore gloves > 2 hours/day	
Bregnhøj et al. ⁵	2012	Denmark	136	Mean 17.7	38.1% wore gloves > 2 hours/day	
Kralj et al. ²⁶	2011	Germany	106 eight-hour shifts. 67 different employees.	Mean 32.7		Glove use comprised 18% of daily wet-work
Nixon et al. ²⁷	2006	Australia	377			30% complained that their hands sweat too much while wearing gloves
Nettis et al. ²⁵	2003	Italy	61	Mean 24.2	Mean 3.4 hours	

Supplementary table 4: Gloves types used by hairdressers

Author	Year	Country	Hairdressers/apprentices (n)	Age	Natural rubber latex (%)	Synthetic rubber (%)	Nitrile rubber (%)	Polyvinylchloride (%)	Polyethylene (%)	Cotton under glove (%)	Rubber household (%)
Piapan et al. ²⁴	2019	Italy	65	Mean 42	68.7	6.3	45.3	15.6	0	6.3	
Lysdal et al. ⁷	2012	Denmark	5324	Mean 36.4	34.9		22.3	35.6	2.1%		0.8
Tresukosol et al. ⁴⁶	2012	Thailand	44	Most common age group 31-40	89%						
Krecisz et al. ²⁸	2011	Poland	139	Mean 18	Most commonly used						
Nixon et	2006	Australia	184	NA	71.2-74.1	23.9-26.5		17.7-23.4			

al. ²⁷											
Lind et al. ¹⁷	2005	Sweden	33	Mean 37	18		3	12	9		
Kanerva et al. ²⁹	1999	Finland	500	NA	19						
Uter et al. ³⁰	1995	Germany	859	NA	19			19	46		31.3

Abbreviations: NA, not applicable