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Management of contact dermatitis

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Abstract As a widespread disease, contact dermatitis affects all age groups with a high prevalence and incidence. In addition to a reduction in the quality of life, it causes considerable health and socioeconomic costs. Essentially, five subtypes can be distinguished, namely irritant contact dermatitis, phototoxic contact dermatitis, allergic contact dermatitis with its two special forms of hematogenous and aerogenous contact dermatitis, photoallergic contact dermatitis, and protein contact dermatitis. The diagnosis is based on a detailed history and clinical skin findings as well as the exposure-related performance of allergological in vivo and in vitro tests. Once the contact substance—irritant or allergen—has been identified, the key to therapeutic success lies in its strict avoidance. Symptomatic therapy of contact dermatitis should always be individualized and based on the stage of eczema. Topical glucocorticoids are considered first-line therapy for both irritant and allergic contact dermatitis. The always accompanying basic therapy with skin care products plays a central role for sustainable therapeutic success. Systemic therapy is considered when topical therapy is ineffective or not feasible. In this context, the short-term use of systemic glucocorticoids should be limited to extensive or clinically severe acute contact dermatitis and exacerbations of chronic contact dermatitis. The efficacy of the use of newer biologics and Janus kinase inhibitors in contact dermatitis is currently being evaluated in several clinical trials.

Keywords Eczema · Occupational dermatosis · Diagnosis · Therapy · Prevention

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Abbreviations

AWMF	Association of the Scientific Medical Societies in Germany
BK	Occupational disease
BKV	Occupational Diseases Ordinance
CCL	C-C motif chemokine ligand
CD	Cluster of differentiation
DDG	German Dermatological Society
DKG	German Contact Dermatitis Research Group
ESCD	European Society of Contact Dermatitis
IL	Interleukin
ILC	Innate lymphoid cell
IVDK	Information Network of Departments of Dermatology for recording and scientific analysis of contact allergies
JAK	Janus kinase inhibitors
LCE genes	Late cornified envelope genes
LST	Lymphocyte stimulation test
LTT	Lymphocyte transformation test
MELISA	Memory lymphocyte immunostimulation assay
mRNA	Messenger ribonucleic acid
MTX	Methotrexate
NLS	Sodium lauryl sulfate
NRF	New formulation formulary
PCR	Polymerase chain reaction
PPD	p-Phenylenediamine
PUVA	Psoralen plus UVA
ROAT	Repetitive open application test
SNP	Single-nucleotide polymorphism
TEWL	Transepidermal water loss
TIX	Therapeutic index
TNF	Tumor necrosis factor
UV	Ultraviolet light
UVA	Ultraviolet rays A

Introduction

Contact dermatitis (synonym: contact eczema) is an inflammation of the epidermis and the adjacent dermis at the site of exposure triggered by external agents. Reactions of the mucous membranes (e.g., oral or genital mucosa) triggered by external agents are not included, as these are not eczema in the narrower sense, although similar pathomechanisms are involved. Eczema that occurs without an external cause, such as atopic dermatitis, idiopathic hyperkeratotic rhagadiform eczema, idiopathic dyshidrotic eczema, or seborrheic eczema, should also be distinguished and will not be discussed further here. The central text sections of this review article are in accordance with the guideline "Contact Dermatitis" of the *Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften* (AWMF; Association of the Scientific Medical Societies) [1].

The clinical picture of contact dermatitis varies mainly depending on its acuity. Clinically, contact dermatitis can be divided into i) acute and chronic forms and ii) mild and marked, severe forms [2, 3]. The acute stage is usually characterized by redness, edema, oozing, crusts, papules, and/or vesicles or blisters. In the chronic stage, plaques are added with increasing infiltration and subsequently scaling, hyperkeratosis, fissures, rhagades, and/or lichenification. Different localizations of contact dermatitis can lead to specific morphologies. On the face, for example, there is often only an angioedema-like swelling of the eyelids. Hyperkeratosis often occurs on the mechanically stressed palms and soles; the mechanically less stressable skin then tends to form rhagades there. The morphology of the primary and secondary efflorescences usually does not allow a reliable differentiation between the various forms of contact dermatitis. The most frequent subjective symptom in all forms of contact dermatitis is clear, often excruciating itching, although pain, burning, and stinging of the skin can also be perceived as further important symptoms.

The most accurate possible diagnostic classification of contact dermatitis is important for disease management, since not only classical eczema therapy but also avoidance of the exogenous triggering factors is of great importance here.

Etiopathogenesis and classification

Individual predispositions (due to genetic factors or inflammatory skin diseases or wounds) and exposures to skin irritants or allergens are the major factors in the development of contact dermatitis.

Contact dermatitis can be classified into five subtypes—with two additional special forms of allergic contact dermatitis, namely hematogenous and aerogenous allergic contact dermatitis (Table 1; [3]).

Irritant contact dermatitis

Numerous contact substances can cause skin irritation in the sense of irritant contact dermatitis through a single (in the case of a very strong irritant), repet-

Table 1 Classification, triggers, and clinical characteristics of contact dermatitis

Contact dermatitis		Trigger	Clinical characteristics
1.	*Irritant contact dermatitis (ICD-10: L24.–)*	Irritants	Sharply limited lesions at contact points, no spreading reactions to other skin areas
			Predilection sites: hands
			Acuity depending on the trigger (type of chemical, water, sweat)
2.	*Phototoxic contact dermatitis (ICD-10: L56.2)*	Chromophore	Mostly sharp border of the lesions
			Predilection sites: light-exposed skin
3.	*Allergic contact dermatitis (ICD-10: L23.–)*	Hapten	Mostly blurred lesions at contact sites, scatter reactions to other skin areas common
			Predilection sites: hands
	Special form: hematogenous contact dermatitis	Hapten	Mostly blurred lesions at contact sites, possible spread reactions to other skin areas
			Predilection sites: intertrigines, gluteal area (so-called "SDRIFE", symmetrical drug-related intertriginous and flexural exanthema)
			Systemic triggering after epicutaneous sensitization to contact allergens
	Special form: aerogenic contact dermatitis	Hapten	Mostly blurred lesions at contact sites, possible spread reactions to other skin areas
			Predilection sites: face, décolleté
			Triggering by aerogenously transmitted contact allergens
4.	*Photoallergic contact dermatitis (ICD-10: L56.8)*	Photoallergens	Mostly blurred boundary of the lesions
			Predilection sites: light-exposed skin
5.	*Protein contact dermatitis (ICD-10: L25.4 or L25.5)*	Proteins	Mostly blurred lesions at contact sites; sometimes preceded by immediate local type symptoms (itching, redness, wheals)
			Possibly combination with inhalative or systemic immediate-type reactions to the same allergen
			Predilection sites: hands, forearms, face
			Individual risk factor: atopic skin diathesis

ICD International Statistical Classification of Diseases and Related Health Problems

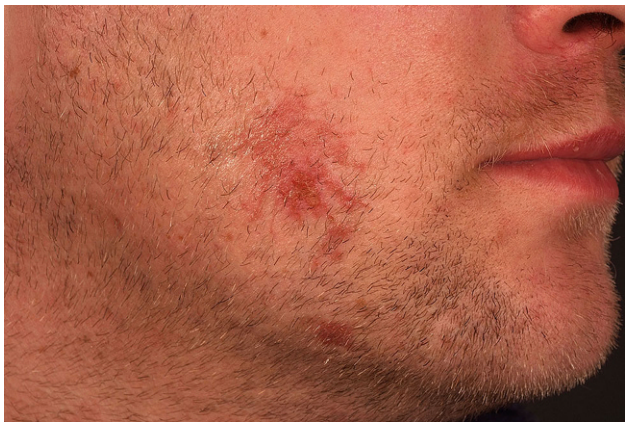

Fig. 1 Acute irritant contact dermatitis on the right cheek of a locksmith caused by splashes of a chemical containing anthracene and carbazole, which is classified as irritant to the skin according to the safety data sheet, during sampling at the workplace. The bizarre clinical picture with finger-shaped extensions is striking. A Medical Accident Report was submitted to the responsible Employer's Liability Insurance Association for Raw Materials and the Chemical Industry (BG RCI). (With kind permission, © Dickel, Heinrich, St. Josef Hospital, UK RUB, all rights reserved)

itive, or chronic exposure to the skin without the involvement of adaptive (specific) immune defenses [4]. These include detergents and other chemicals as well as water and sweat after occlusion of the skin. Exposure of the hands is of particular importance in this context [5].

Depending on the course (and dermatological school), such eczema is called acute irritant contact dermatitis (Fig. 1), acute toxic contact dermatitis, chronic irritant contact dermatitis, cumulative (sub)toxic contact dermatitis, or degenerative contact dermatitis. A special case is phototoxic contact dermatitis, which is caused by combined exposure to a phototoxic contact substance (e.g., benzocaine, benzoyl peroxide, ketoprofen, tretinoin, tar derivatives, psoralens, and other herbal furanocoumarins [6]) and ultraviolet (UV) light (Fig. 2; [7]).

Direct exposure to skin irritants leads to superficial inflammation of the skin, in which proinflammatory mediators from keratinocytes (such as interleukin [IL]-1, IL-6, IL-8, or tumor necrosis factor [TNF]-α) in particular are significantly involved in the initial phase. The chemokines and other proinflammatory mediators released during this phase lead to an infiltration of mononuclear cells, especially T cells, which characterize the histological and clinical picture of irritant contact dermatitis.

Allergic contact dermatitis

Allergic contact dermatitis may occur after previous sensitization to a contact substance (Figs. 3 and 4a; [4]). The triggering allergen contact is then generally direct skin contact. However, it can also be triggered

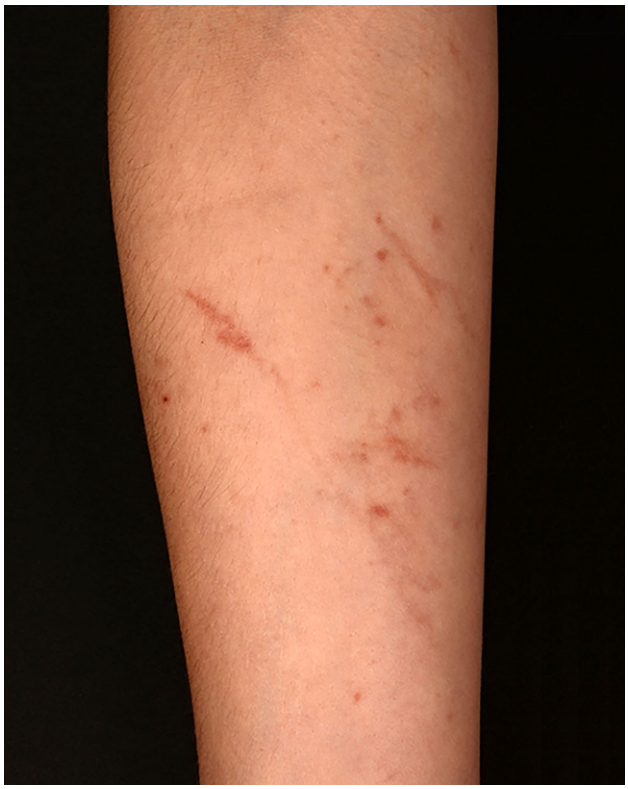

Fig. 2 Phototoxic contact dermatitis on the inner side of the forearm after contact with a plant containing phototoxic substances and subsequent exposure to sunlight (meadow grass dermatitis). A typical feature is the streaky smear of the plant in question at the points of contact. Most of the triggering substances are from the group of psoralens (furanocoumarins) and are contained in the leaves, stems, and fruit clusters of the plant. (With kind permission, © Dickel, Heinrich, St. Josef Hospital, UK RUB, all rights reserved)

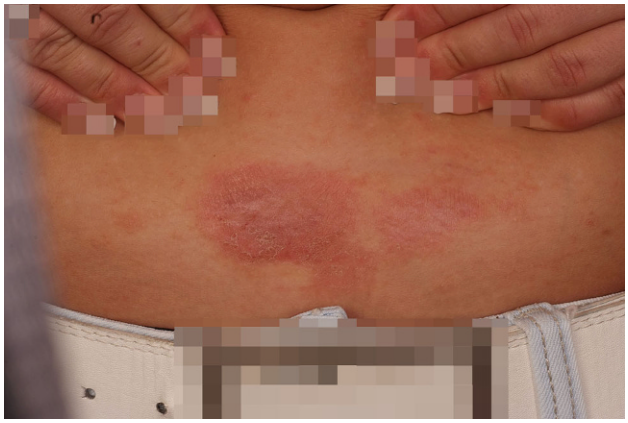

Fig. 3 Allergic contact dermatitis to nickel. The trigger identified by dimethylglyoxime testing was a trouser button releasing nickel ions and a belt buckle releasing nickel ions above it. The patient was previously known to be intolerant to costume jewelry in the context of wearing earrings. Patch testing demonstrated delayed-type sensitization to nickel sulfate. (With kind permission, © Dickel, Heinrich, St. Josef Hospital, UK RUB, all rights reserved)

by a systemic allergen supply (so-called hematogenous contact dermatitis) or an aerogenous allergen contact (so-called airborne contact dermatitis).

Allergic contact dermatitis is usually caused by a delayed-type sensitization mediated by contact allergen-specific T cells (so-called type IV sensitization). More than 5000 contact substances can lead to the development of allergic contact dermatitis [8]. The immune reaction takes place against the body's own proteins or peptides, which only become immunogenic through the binding of low-molecular contact allergens (haptens) [9]. A clinically invisible sensitization phase lasting approximately 10–15 days must be distinguished from the trigger phase of allergic contact dermatitis, which becomes clinically visible as an eczema reaction a few hours to days after renewed allergen contact.

In the sensitization phase, low-molecular-weight contact allergens pass through the stratum corneum into the deeper layers of the skin, where they bind to endogenous proteins. Some allergens must be altered by enzymatic activation or by chemical or physical reactions such as oxidation in the skin before they can become immunoreactive [10]. In particular, enzymes of xenobiotic metabolism such as cytochrome P450, acetyltransferases, and sulfatases are involved in this process [11, 12].

Many contact allergens themselves have an irritant potential or adjuvant effect, resulting in the activation of signaling receptors of the innate immune system or the release of endogenous danger signals (damage-associated molecular patterns, [DAMPs]) [9]. For example, nickel binds to the human Toll-like receptor 4 [13] and directly activates antigen-presenting cells and skin macrophages. Chromium, on the other hand, activates in inflammatory cells the NLRP3 inflammasome [14].

After migration of activated antigen-presenting cells and their maturation in the lymph node, the hapten–peptide complex is presented there to T lymphocytes.

After renewed skin contact with the corresponding contact allergen, the triggering phase of allergic contact dermatitis is initiated. In addition to activation by a hapten–peptide complex, direct activation of T lymphocytes can also occur, as described for p-phenylenediamine (PPD) [15]. Undoubtedly, T cells together with the directly interacting antigen-presenting dendritic cells represent the most important effector cells in allergic contact dermatitis at this stage. However, in in vivo mouse models, important roles of mast cells, neutrophils and, in recent years, of innate lymphoid cells (ILCs) involved in the regulation of the eczema response in contact allergy have also been elaborated [9].

Secondary barrier disorders develop due to misregulation of epidermal barrier molecules in lesional eczematous skin, and are involved in the disease process of contact dermatitis.

A number of risk factors may increase the likelihood of contact sensitization. These include preexisting wounds or cutaneous inflammation with upregulation of proinflammatory cytokines in skin [16]. Clinically relevant is further the observation that a combination of (weak) contact allergens with each other, with penetration enhancers, with phthalates (which are often used as emollients), or with skin irritants such as sodium lauryl sulfate (NLS) can significantly increase the rate of sensitization [9].

In addition, genetic factors have been identified that generally do not appear to increase the overall risk of contact allergy, but only the risk of sensitization to specific contact allergens, such as a single-nucleotide polymorphism (SNP) in the gene encoding TNF-α with increased risk of sensitization to PPD [17, 18]. Polymorphisms of xenobiotic-metabolizing enzymes may also influence the risk of contact sensitization [19]. Furthermore, genetically determined alterations of skin barrier proteins have been described in contact dermatitis. This concerns deletions of certain late cornified envelope (LCE) genes as well as SNPs in the tight junction protein claudin-1. Heterozygous loss-of-function mutations of the epithelial protein filaggrin with consecutive skin barrier disorders not only represent a strong risk factor for the development of atopic dermatitis [20] but have also been described in combined irritant and allergic contact dermatitis [21, 22].

As in irritant contact dermatitis, there is a special form of allergic contact dermatitis caused by the combined action of a photosensitizer (e.g., etofenamate, ketoprofen, organic photoprotective filters such as benzophenone-3 [6]) and UV light, namely photoallergic contact dermatitis (Fig. 5).

Protein contact dermatitis

More rarely, immunoglobulin E-mediated allergy (so-called type I sensitization) leads to contact dermatitis, namely protein contact dermatitis (Fig. 6; [23]). Typical triggers are allergenic proteins of plant origin (e.g., cereals, latex [24]) or animal origin (e.g., meat, marine animals [25]). Protein contact dermatitis may manifest as eczema of the fingertips only or may extend to the hands, wrists, and forearms [23, 26]. In the case of aerogenic skin contact due to, for example, released vapors, all exposed body parts, such as the face and neck, may be affected as well [27, 28].

The clinical feature of protein contact dermatitis is that, in the sense of immunological contact urticaria, acute episodes of itching, wheals, edema, or vesiculation occur a few minutes after contact with the allergenic protein [29]. Some cases of chronic paronychia are considered a variant of protein contact dermatitis [23].

Epidemiology

Allergic and irritant contact dermatitis are common diseases that cause considerable health and socioeconomic costs in addition to the suffering of the affected individuals [30, 31]. Irritant contact dermatitis is far more common than allergic contact dermatitis, accounting for approximately 80% of all cases [32].

In all data on the epidemiology of allergic contact dermatitis, a distinction must always be made between contact sensitization as such and allergic contact dermatitis as a clinical manifestation of contact sensitization.

Prevalence

In a European multicenter study on the prevalence of contact allergy (2008–2011), 15% of respondents reported having ever suffered from allergic or irritant contact dermatitis [33]. In just over half of the cases (8%), this was confirmed by a physician. In an extensive evaluation of the scientific literature on hand eczema of the years 1964–2007 by Thyssen and coworkers [34], a point prevalence of hand eczema of about 4%, a 1-year prevalence of about 10%, and a lifetime prevalence of 15% were found, whereby all forms of hand eczema were considered. By means of questionnaires and physician interviews, a lifetime prevalence of allergic contact dermatitis of about 15% and a 1-year prevalence of about 7% were determined in the 1998 Federal Health Survey in Germany, with women being affected about twice as often as men [35].

Allergic contact dermatitis affects all age groups, from children to seniors [36–38]. Some studies indicate an increasing prevalence of both allergic contact dermatitis and contact sensitization in children [39]. In the first follow-up survey of the Study on the Health of Children and Adolescents in Germany (KiGGS study, first wave, 2009–2012), the 1-year prevalence of allergic contact dermatitis in children and adolescents (0–17 years) was 2.2%, with girls (2.4%) not significantly more affected than boys (2.0%) [40]. The most common irritant contact dermatitis in the first year of life (maximum: 9th–12th month of life) is diaper dermatitis [41].

In the aforementioned European multicenter study on the prevalence of contact allergies (2008–2011) [33], 27% of those examined reacted in the patch test to at least one allergen of the European baseline series. Study participants who had previously suffered from contact dermatitis showed a 1.9-fold increased risk in this regard. Women had a significantly higher reaction rate than men, mainly due to the much more frequent nickel allergy. A recent meta-analysis of studies on the prevalence of contact allergy in the general population concludes identically that at least 20% of the population is sensitized to a contact allergen [37]. Based on an extrapolation of clinical epidemiological data from the *Informationsverbund Dermatologischer Kliniken* (IVDK) from 1992–2000, a 9-year prevalence of contact sensitization to at least one allergen from the standard series of 4.0–16.6%—depending on the assumed scenario—was calculated [42]. From the calculations related to individual allergens, it was found that, for example, between 1.9 and 4.5 million Germans are sensitized to nickel.

In contrast, no current data are available on the prevalence or incidence (see below) of irritant contact dermatitis in the general population. Although population-based studies are also lacking in this area [28], protein contact dermatitis is rare in the general population [43]; its prevalence in food-processing occupations alone (e.g., fishing and seafood processing industries) worldwide is estimated to be as high as 11% [43, 44].

Incidence

A 1982 Dutch study of a population sample of nearly 2000 adults (30–61 years old) found an incidence rate of 7.9 new cases per 1000 persons per year for eczema of the hands or forearms of any etiology [45].

Based on data from the IVDK for 1992-2000, the incidence rate of allergic contact dermatitis was calculated to be 1.7–7 new cases per 1000 population per year [42].

Diagnostics

Medical history and clinical examination

The anamnesis is a guideline for further diagnostics. It should be structured and include information regarding current symptoms, duration and course of the disease, exacerbations and recurrences in connection with occupational and private activities, family and personal history regarding atopic diathesis (atopic dermatitis, allergic rhinoconjunctivitis, allergic asthma) [46–48], previous and currently existing skin and systemic diseases, regular medication use, and nicotine consumption [49]. Sharp-edged skin lesions suggest an irritant/toxic genesis, scattered phenomena suggest an allergic genesis of contact dermatitis, and combinations are not uncommon [50]. Especially on the hands, the occurrence of multifactorial contact dermatitis is frequently observed [51, 52].

Exposure to contact substances, the clinical picture, the improvement in findings after abstinence from contact substances or the persistence of findings despite antieczematous therapy appropriate to the stage lead to the suspicion that the eczema is caused by contact with an exogenous trigger (Table 1). In irritant contact dermatitis, this is primarily due to the effects of skin-irritating contact substances (irritants) such as frequent and prolonged contact with water, solvents, detergents, or dusts, which preferentially cause an ir-

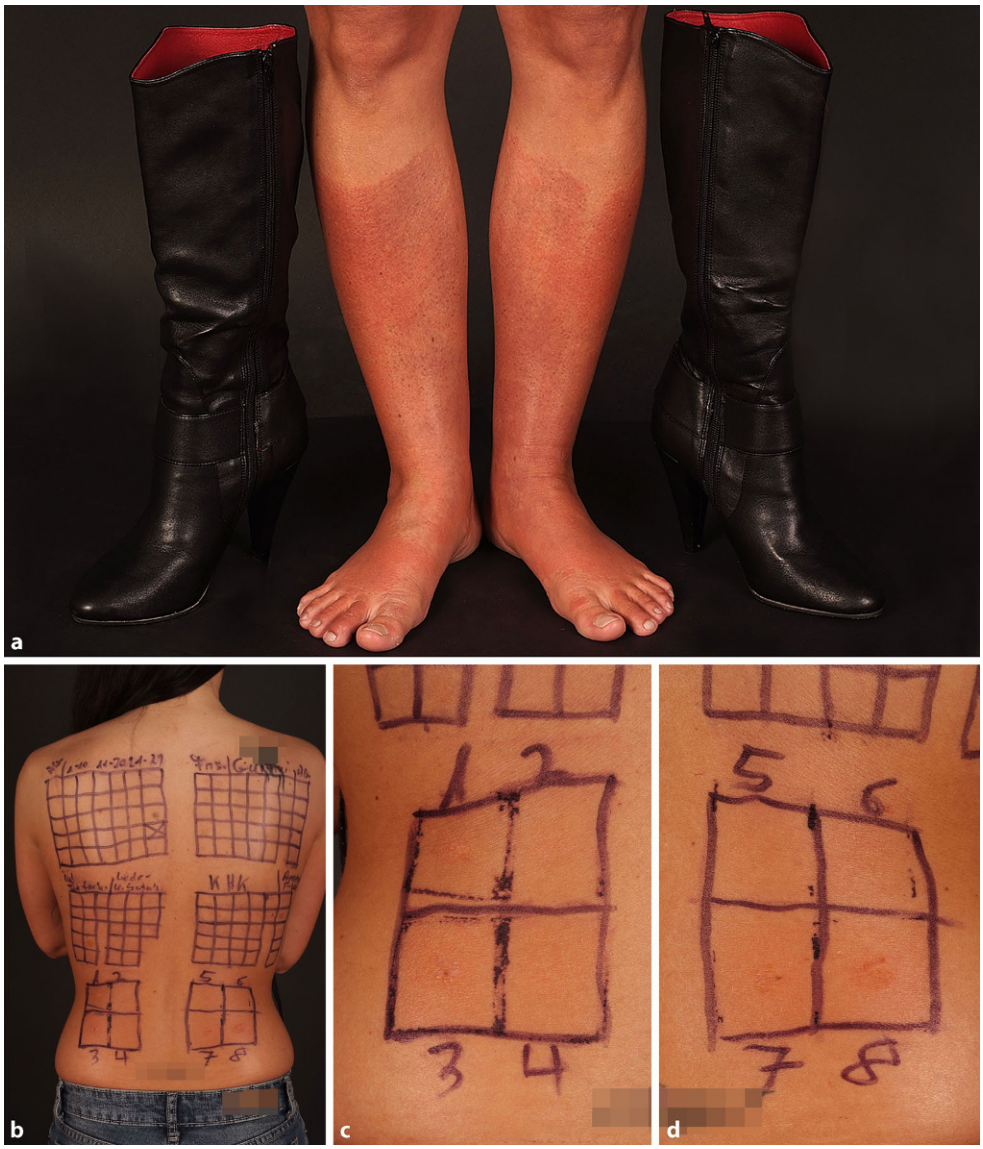

Fig. 4 **a** Allergic contact dermatitis to component(s) of red-leather-lined black synthetic leather boots. **b** Patch test at 72 h reading. **c** Single positive skin reactions to red leather exterior—dry (field 1), and red leather exterior—moist (field 3), and **d** red leather interior—dry (field 7), and red leather interior—moist (field 8). In all other patch test fields, no positive skin reactions could be objectified. Attempts to obtain information on the shoe components from the retailer or distributor were unsuccessful. (With kind permission, © Dickel, Heinrich, St. Josef Hospital, UK RUB, all rights reserved)

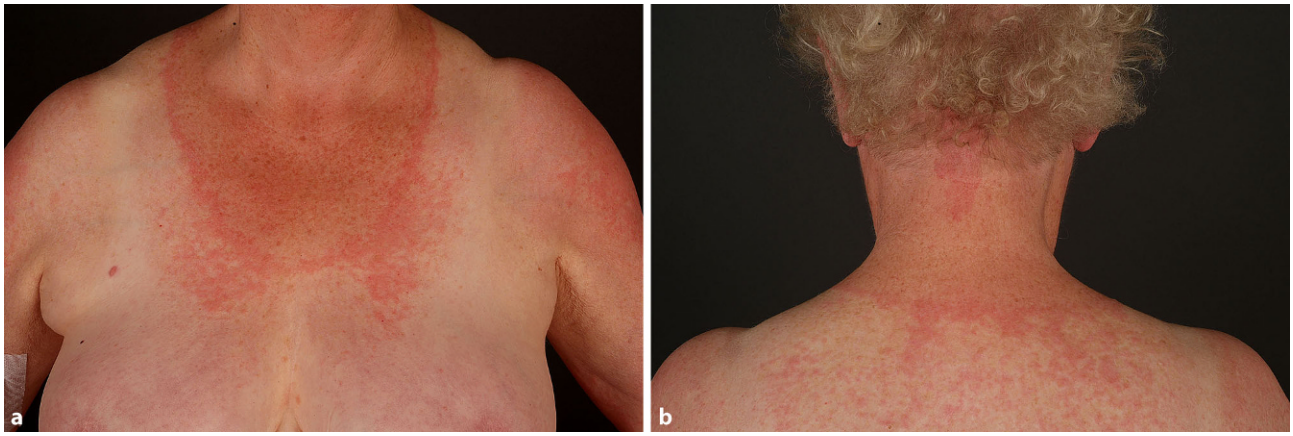

Fig. 5 Photoallergic contact dermatitis after application of a sunscreen, especially in the décolleté (**a**) and neck area (**b**). The patient did not show up for the scheduled photopatch test. (With kind permission, © Dickel, Heinrich, St. Josef Hospital, UK RUB, all rights reserved)

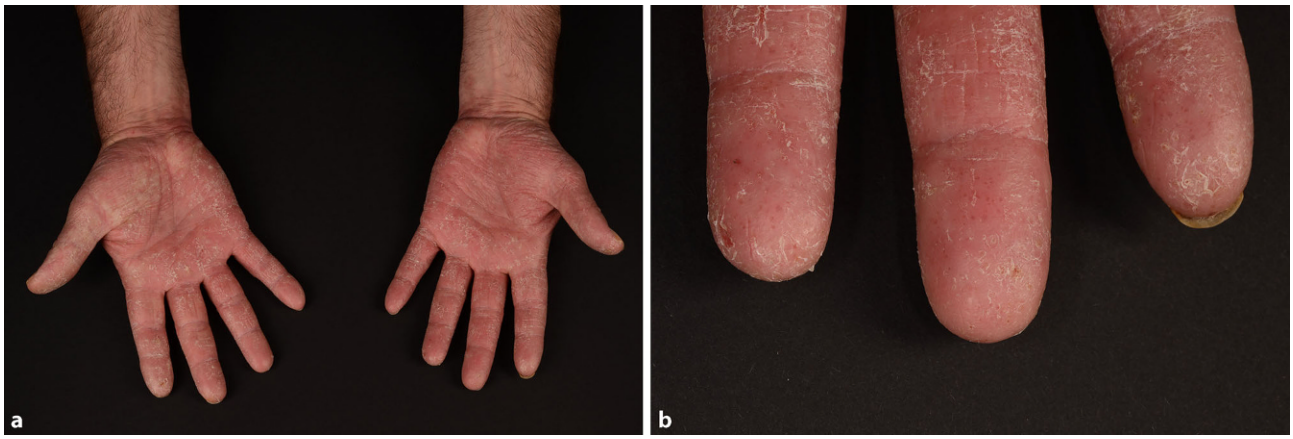

Fig. 6 Chronified protein contact dermatitis with the clinical picture of a contact dermatitis in a baker ("baker's eczema"), mainly hyperkeratotic on the palms (**a**) and dyshidrotic in places on the finger extremities (**b**). The prick test with native material showed double-positive skin reactions to rye flour type 1150 and wheat flour type 550. Correlatively, specific IgE to rye and wheat flour was found. The responsible professional association for food and catering (BGN) approved the further treatment within the framework of the dermatologist's procedure. (With kind permission, © Dickel, Heinrich, St. Josef Hospital, UK RUB, all rights reserved)

ritant skin reaction. In phototoxic contact dermatitis, it is the effects of contact substances containing chromophores together with UV radiation. In allergic contact dermatitis, contact with contact allergens (haptens), and in photoallergic contact dermatitis, contact with photoallergens in conjunction with exposure to UV radiation is causative, and in protein contact dermatitis, contact with proteins.

For a number of occupations, because of the complexity of the possible exposures, "anamnesis auxilia" have been developed [53–60].

Delayed-type/type IV diagnostics

Patch test

Since contact dermatitis often cannot be differentiated with absolute certainty with regard to causality (Table 1), at least a single patch test is strongly recommended in chronic or chronically recurrent cases, even in forms that initially suggest an irritant etiology [61]. Although type I allergies are more frequent than type IV allergies in children [62], allergic contact dermatitis is not uncommon in children and should be considered for differential diagnosis, especially when children with refractory eczema are treated [63]. Since certain contact allergens are rarely considered as triggers in children, due in part to the lack of exposure, it is medically necessary to use an appropriately adapted baseline series for children (e.g., https://dkg.ivdk.org/testreihen.html#a002, last accessed Jan. 28, 2023) for patch testing [63, 64].

The diagnosis of allergic contact dermatitis is made by detecting contact sensitization to the causative allergen in the patch test (Fig. 4b–d). Indication, performance, and relevance evaluation of the patch test are described in detail in the corresponding AWMF guideline "Performance of the patch test with contact allergens and drugs" [65, 66]. Important is the exposure-adapted selection of the a series taking into account private and occupational exposures [67], the use of tested test preparations (e.g., as in the test series recommended by the German Contact Dermatitis Research Group [DKG]; https://dkg.ivdk.org/testreihen.html, last accessed Jan. 28, 2023), the application of patient-own substances in suitable test concentrations, methodically correct dosing and application, and the reading of the test reactions at least until the third day and, in the case of certain contact allergens, additionally 7–10 days after the start of the test [65, 66, 68–70]. After the patch test results become available, questions about allergen exposure must be repeated frequently in a follow-up history. Due to the frequency of reactions in the patch test, the test allergens of the DKG baseline series (https://dkg.ivdk.org/testreihen.html#a001, last accessed 28.01.2023) are always of particular importance (Table 2).

If no plausible results are obtained with a conventional patch test with regard to a suspected contact allergy and the clinical suspicions persist, a modified procedure of the patch test (strip patch test) and a specific-use test (repetitive open application test, ROAT) can be considered. Their application requires special experience.

Strip patch test

In cases where the results of a conventional patch test are suspected to be false negative, a standardized and validated strip patch test [71–74] is recommended [61, 66]. In the strip patch test, adhesive tape tear-offs in the test area before application of the test preparation aim to increase the test sensitivity [75, 76].

The strip patch test is generally recommended 1) in case of non-positive or non-allergic conventional patch test reaction and persisting suspicion of

Table 2 Relative reaction frequencies of DKG baseline series allergens in the IVDK over the course of 2018–2021[a]

Test preparation with test concentration	Year	2018	2019	2020	2021
	Number of patients	10,263	10,080	8489	8466
1. Nickel sulfate 5% Vas.		16.0%	17.1%	16.4%	16.2%
2. Cobalt chloride 1% Vas.		7.3%	7.1%	6.6%	7.1%
3. Balsam of Peru 25% Vas.		5.2%	5.9%	6.3%	5.9%
4. Propolis 10% Vas.		4.1%	4.3%	4.5%	5.5%
5. Potassium dichromate 0.5% Vas.		4.6%	4.8%	4.8%	4.8%
6. Fragrance mix 8% Vas.		5.5%	5.3%	5.4%	4.6%
7. Colophonium 20% Vas.		3.4%	4.2%	3.7%	3.1%
8. MDBGN (dibromdicyanobutane)[b,c] 0.3 and 0.2% Vas.		4.1%	4.0%	n. s. T.	n. s. T.
9. Fragrance mix II 14% Vas.		3.4%	3.7%	3.0%	3.0%
10. Methylisothiazolinone 0.05% Vas.		3.2%	3.1%	2.6%	2.5%
11. Methylchloroisothiazolinone + Methylisothiazolinone (MCI/MI) 100 ppm Aqu.		3.0%	2.8%	2.3%	2.3%
12. Thiuram mix 1% Vas.		2.5%	2.3%	2.3%	2.3%
13. Ylang-ylang (I + II) oil 10% Vas.		2.1%	2.0%	2.3%	2.2%
14. 2-Hydroxyethyl methacrylate (HEMA)[d] 1% Vas.		n. s. T.	2.2%	1.5%	1.4%
15. Lanolin (wool alcohols) 30% Vas.		1.6%	1.5%	1.5%	1.4%
16. Epoxy resin 1% Vas.		1.5%	1.5%	1.5%	1.3%
17. Compositae mix II 5% Vas.		1.2%	1.3%	1.4%	1.2%
18. HICC (Lyral) 5% Vas.		1.4%	1.4%	1.2%	1.1%
19. Jasmine absolute 5% Vas.		1.2%	1.2%	0.9%	1.1%
20. Formaldehyde 1% Aqu.		1.1%	1.0%	0.8%	0.8%
21. Sandalwood oil 10% Vas.		1.2%	1.1%	1.0%	0.8%
22. Paraben mix[2] 16% Vas.		0.9%	0.9%	n. s. T.	n. s. T.
23. Iodopropynyl butylcarbamate 0.2% Vas.		0.6%	0.8%	0.7%	0.7%
24. Sorbitan sesquioleate 20% Vas.		0.6%	0.8%	0.8%	0.7%
25. Mercaptobenzothiazole (MBT) 2% Vas.		0.6%	0.7%	0.7%	0.5%
26. Zinc diethyldithiocarbamate[e] 1% Vas.		0.7%	0.7%	n. s. T.	n. s. T.
27. Cetylstearyl alcohol[c] 20% Vas.		0.7%	0.5%	n. s. T.	n. s. T.
28. N-isopropyl-N′-phenyl-p-phenylenediamine (IPPD) 0.1% Vas.		0.9%	0.8%	0.8%	0.4%
29. Mercapto mix (without MBT) 1% Vas.		0.5%	0.4%	0.5%	0.4%
30. Turpentine 10% Vas.		0.3%	0.3%	0.3%	0.2%

Aqu. in water, *n. s. T.* selective tests only, *ppm* parts per million, *Vas.* in petrolatum
[a]Quality-checked data; age- and sex-standardized percentages of positive reactions, patch test reactions on day 3 or day 4 unless read on day 3 (IVDK database status: 5/11/2022; Geier J, personal communication, 11/14/2022)
[b]MDBGN: increase of test concentration from 0.2 to 0.3% petrolatum on 4/1/2016
[c]MDBGN, paraben mix, and cetylstearyl alcohol were moved from the DKG baseline series to the DKG preservative series and DKG external ingredient series, respectively, as of 7/1/2019
[d]2-Hydroxyethyl methacrylate (HEMA) was newly added to the DKG baseline series on 7/1/2019
[e]Zinc diethyldithiocarbamate moved from DKG baseline series to DKG rubber series effective 1/1/2020

contact allergy, 2) in case of pre-described delayed-type sensitization not reproduced in the conventional patch test, 3) in case of test preparations with low corneal layer permeation (e.g., metal salts, heparins, aminoglycosides, etc.), or 4) in case of reduced penetration capacity at the test area (e.g., dental metals, ophthalmics, etc.) [66, 73]. The test should be performed in a standardized manner according to the procedure developed by Dickel et al. on behalf of the DKG [77] and following the validated protocol ([71, 74]; Table 3).

Repetitive open application test

In addition, a ROAT may be considered to rule out a false-positive patch test reaction and to confirm contact sensitization [66]. Using a ROAT [78, 79] as a "use test" generally replicates the actual application situation of a product by the patient, such as ointments, creams, lotions, or solutions.

In the ROAT, the test preparation (commercial product or special test substance) is applied to the same skin site (e.g., inside of the forearm) twice daily (morning and evening) for up to 14 days [80]. As a guideline for the amount to be applied, 0.02 ml on an area of 3 × 3 cm is recommended. The test area should be read daily. As soon as a positive test reaction occurs (at least weak erythema covering ≥ 25% of the test area, with at least one papule as an expression of an infiltrate), further application is stopped.

Table 3 Protocol for the standardized performance of the strip patch test. (Pictorial representation in [72])

1.	3M™ Blenderm™ surgical tape (width 25 mm) is used	
2.	If hair removal is necessary, clippers are used (e.g., 3M™ surgical clipper)	
3.	Stripping of the healthy skin at one upper part of the back is done until the stratum lucidum is reached, i.e., the surface shows three small glistening spots	
	(1)	Tape is vertically (parallel to the spine) applied onto the skin without tension
	(2)	Tape is smoothed out and gently pressed downward by fingertips for about 2 s
	(3)	Tape is removed in one quick movement at an angle of 45° in the direction of adherence
	(4)	For each single strip a new tape cut is used and positioned on exactly the same skin area
4.	The number of tape strips required to produce three small glistening spots is multiplied by the tape-specific correction factor $cf = 11/26 \approx 0.42$	
5.	The calculated number of tape strips is applied contralateral and/or lateral to spine:	
	I.	Tape strips are performed as specified by the items 3.(1) to 3.(4)
	II.	The filled patch test device (e.g., Finn Chamber® on Scanpor® tape) is then applied and fixed
	III.	Patch test is removed after 24 h
	IV.	Test results are read according to the guidelines of conventional patch testing
3M Deutschland GmbH, Neuss, Germany; SmartPractice Europe GmbH, Greven, Germany		

Photopatch test

A photopatch test (UVA-irradiated patch test) should always be performed if the presence of a photoallergic—differential diagnosis phototoxic—skin reaction is suspected [81, 82]. With regard to a photopatch test series, extensive adoption of the proposal of the European Society of Contact Dermatitis (ESCD) and the European Society for Photodermatology for a European photopatch test baseline series is recommended [83].

In the photopatch test, in contrast to the conventional patch test, the test preparations are applied twice. After 24 h, one test block is removed and irradiated with UVA (5 J/cm^2). A reading in the exposed area is taken before and immediately after exposure (i.e., 24 h after application of the test preparations) and after 48 and 72 h. After 24 and 48 h, the test block of the non-irradiated test is also removed and the test responses in the unexposed area are read at the same time intervals [81, 82, 84]. Observation of the reaction over a 72-hour period facilitates differentiation between phototoxic and photoallergic reactions: the latter is characterized by a delayed onset with a crescendo course—in addition to erythema and infiltrate, papulovesicles, blisters, or erosions are often found. The phototoxic reaction is usually characterized by a maximum in the early phase followed by a decrescendo course—usually only erythema and infiltrate are found [84].

Lymphocyte transformation test

For scientific or special clinical questions (e.g., in the case of contact substances that are toxic or carcinogenic even at low concentrations), the lymphocyte transformation or stimulation test (LTT or LST) and its modifications (e.g., memory lymphocyte immunostimulation assay, MELISA) are used as in vitro tests [85]. To date, no interlaboratory tests exist as a basic instrument for quality assurance of the LTT.

From a dermatological point of view, there is rarely a clinical indication to prefer the complex and for most contact allergens not validated in vitro test to skin tests, so that the actual value of the LTT in relation to contact allergies is to be seen in the clarification of scientific questions (also with regard to possible further developments of this test system). An uncritical use of LTT (or modifications like MELISA), e.g., for the clarification of alleged mercury allergies, should be rejected [86].

Irritation tests

A useful test for direct detection of irritant contact dermatitis is not available [87]. Alkali resistance testing, the nitrazine yellow test, or a measurement of transepidermal water loss (TEWL) do not provide reliable decision aids [88]. Therefore, the diagnosis of irritant contact dermatitis is derived from the history and clinical picture after exclusion of causative contact sensitizations and can be indirectly confirmed by successive healing after cessation of contact substance exposure.

Immediate-type/type I diagnostics

In protein contact dermatitis as well as in contact urticaria, which may be associated with it, specific IgE antibodies are determined in vitro on the basis of the patient's history and open application tests (e.g., friction test) and/or prick tests are performed in vivo [89].

In an open application test, the protein-containing contact substance is placed or rubbed on the intact skin [29, 90]. Because test results on intact skin are often false-negative, it is important to test the native material on lesional skin as well. The open application test is considered less hazardous than invasive methods such as the prick test. Therefore, some authors recommend open application testing before performing more invasive tests [91]. Prick testing should be performed according to the recommendations of published guidelines [92].

Often a prick-to-prick test with native material is required [89, 93]. The prick-to-prick test—embedding the skin prick lancet in the native material prior to the actual prick [91]—may be more sensitive than prick testing with commercially available allergen extracts [89, 94], especially if the native material is at the same stage of preparation as when the allergic reaction is triggered [29, 94]. When testing with fresh native ma-

Table 4 Important differential diagnoses of contact dermatitis

Differential diagnoses
Atopic dermatitis
Nummular eczema
Congestive dermatitis
Psoriasis
Seborrheic eczema
Mycosis
Cutaneous T-cell lymphoma
Lichen planus
Pityriasis rosea
Lupus erythematosus
Dermatomyositis

terial, caution should generally be exercised with regard to possible transmission of infectious diseases, and testing of control subjects should be avoided [91].

Histology

Histopathologic examination of a skin biopsy is indicated in all cases of contact dermatitis that are not typical clinically or due to the course of the disease and is also required to exclude differential diagnoses (e.g., psoriasis, lymphoma, lichen planus; Table 4).

Particularly on the hands, where different exposures may act cumulatively, even histopathologically can differentiation between psoriasiform eczema and eczematized psoriasis often be difficult. Molecular approaches to differentiation using, for example, the two biomarkers nitric oxide synthase 2 (NOS2) and C-C motif chemokine ligand (CCL) 27 as classifiers quantified based on isolated total messenger ribonucleic acid (mRNA) from tissue samples using polymerase chain reaction (PCR) are currently being investigated [95, 96].

Mycology

The possibility of a dermatophyte infection (tinea) or yeast infection (candidiasis) should always be considered and excluded in the differential diagnosis. Unilateral cases of hand eczema are particularly suspicious in this regard. Therefore, skin swabs with scale material should be taken for microscopy and culture and, if available, for PCR [97]. Finally, dermatophyte infection on the feet may cause dermatophytid reactions on the hands as a concomitant disease or cofactor of hand eczema.

Differential diagnoses

A number of other eczema diseases, such as the common atopic dermatitis, must be differentiated from contact dermatitis in terms of differential diagnosis. The most important differential diagnoses are listed in Table 4. They should be considered depending on the acuity, morphology, and localization of the contact dermatitis.

Diaper dermatitis occurs in infancy and is usually an irritant contact dermatitis. The main differential diagnoses are psoriasis and seborrheic eczema, which typically involve the diaper area [98].

Contemporary therapeutic management

With regard to the partly overlapping therapeutic management of contact dermatitis and hand eczema, the relevant guidelines on hand eczema of the German Dermatological Society (DDG) are additionally referred to [99], as are those of the ESCD [52]. Specific aspects of the therapy of anal eczema are described in the AWMF guideline "Diagnostics and therapy of anal eczema" [100].

Identification and avoidance of the contact substance

In contact dermatitis, the basis of therapy is identification of the triggering contact substance (irritant and/or allergen) and education of the patient about it [101–104]. Once the contact substance has been identified, the prognosis of contact dermatitis depends crucially on subsequent contact avoidance or at least significant contact minimization [102]. Successful contact avoidance is the most important prerequisite for long-term remission, as no other causal therapeutic approach has been established to date [105]. For example, the prognosis for nickel or chromate allergy is generally poor because they are ubiquitous contact allergens that are difficult to avoid, whereas the prognosis for contact allergens that are easy to identify and avoid is good [102].

Anti-inflammatory therapy

Anti-inflammatory therapy for contact dermatitis must always be adapted to the specific individual situation [104]. In this context, it is important to treat acute contact dermatitis quickly and effectively to prevent chronification [52, 99, 102, 103].

The choice of therapy should be based on the acute nature, clinical severity, morphology of the lesions, and localization [102]. A needs-adapted combination of topical therapy, physical therapy, and systemic therapy is required, although not all forms of therapy need to be performed simultaneously but can be used in a varied fashion [103, 106]. For example, systemic therapy may be necessary if adequate topical therapy alone is not sufficiently effective.

Glucocorticoids

Topical glucocorticoids exhibit an anti-inflammatory, immunosuppressive, and antiproliferative mechanism of action [104, 107]. They have proven effective

in clinical practice in the treatment of irritant and allergic contact dermatitis [102], including hand eczema [52, 99]. The choice of a particular glucocorticoid should balance its efficacy with its adverse effects; skin atrophy and development of telangiectasia are common side effects [107]. The therapeutic index (TIX) was developed as a decision aid (TIX = 1 ≙ poor; TIX = 2 ≙ moderate; TIX = 3 ≙ good) [107, 108]. Glucocorticoids with higher TIX (group 2, TIX ≥ 2) have a more favorable ratio of efficacy to adverse effects, whereas group 1 glucocorticoids have a less favorable ratio (TIX < 2). In general, group 2 glucocorticoids with a TIX ≥ 2 (e.g., prednicarbate, methylprednisolone aceponate, mometasone furoate) should be chosen [52, 99, 103]. In acute and severe contact dermatitis episodes, it is advisable to use sufficiently potent glucocorticoids to rapidly suppress inflammation, even if they have a lower TIX. In chronic contact dermatitis with lichenification and hyperkeratosis, therapy with the most potent glucocorticoids is indicated because of their antiproliferative effect and presumed lower penetration [99]. Low-potency glucocorticoids should be used in intertriginous skin areas and in the facial and anogenital regions [100]. Long-term use of high-potency topical glucocorticoids should be avoided not only because of their local side effects [107], but also because of possible consequences of their absorption, such as osteoporosis [109, 110], should they be limited. Intermittent and proactive treatment regimens—application, for example, twice a week for up to 6 months—may help to reduce side effects [111].

Topical glucocorticoids are available in various bases, such as lotions, creams, and ointments. Their choice should be based on acuity and morphology, as in the case of basic therapy (see section "Basic therapy" below). It should be noted that the same glucocorticoid agents may develop different efficacy depending on the base. Contact allergy to the glucocorticoid or other ingredient in the preparation should be considered and ruled out by patch testing if the skin condition worsens or does not improve with treatment [52, 99, 101, 107, 112–114].

Systemic glucocorticoids may be indicated for extensive or severe acute contact dermatitis and exacerbations of chronic contact dermatitis—usually short-term (up to maximum 2 weeks) 0.5–1 mg/kg body weight [bw]/day prednisolone equivalent with rapid tapering off [52, 99, 102, 103]. Their long-term or frequent use is not indicated in contact dermatitis or hand eczema because of the known side effects [52, 99, 104, 106, 107, 112, 115].

Topical calcineurin inhibitors

The topical calcineurin inhibitors tacrolimus and pimecrolimus are immunomodulators. They represent an alternative to topical glucocorticoid therapy—however, with approval in Germany exclusively for atopic dermatitis [103, 116]. Their advantage is their safety in long-term use due to the lack of skin atrophy risk [104, 117] and the lack of disturbance in restoration of the skin barrier [102, 103]. Calcineurin inhibitors have been shown to be effective in experimental human models of nickel- and diphenylcyclopropenone-induced allergic contact dermatitis [118, 119] and sodium lauryl sulfate-induced irritant contact dermatitis [120, 121]. Their anti-inflammatory potency reaches that of low- to moderate-strength glucocorticoids, such as 0.1% hydrocortisone butyrate or 0.1% betamethasone-17-valerate [118, 119, 122].

Because of the potential photocarcinogenicity, sunlight exposure of the skin should be avoided during topical calcineurin inhibitor therapy and UVA/B or PUVA light therapy should not be performed [102].

Janus kinase inhibitors

Janus kinase (JAK) inhibitors modulate Th2, Th22, Th1, and Th17 signaling pathways, among others, and have selective immunosuppressive, anti-inflammatory, and antiproliferative properties [102]. Since they are small molecules, they can penetrate the skin barrier and are therefore important not only for systemic but also for topical application, for example, in hand eczema [103].

Delgocitinib, a novel topical pan-JAK inhibitor, was investigated for the treatment of chronic hand eczema in a randomized controlled trial [123]. The therapeutic success was shown to be independent of the dominant subtype of chronic hand eczema—irritant or non-irritant.

Systemic retinoids

Alitretinoin (9-cis-retinoic acid) has proven efficacy and approval for the treatment of severe chronic hand eczema unresponsive to standard therapy [52, 99, 102–104, 106, 112, 124]. The standard therapeutic dose is 30 mg/day for a period of 3–6 months [124]. Alitretinoin is considered suitable for intermittent long-term therapy of hand eczema [52, 99, 102, 104, 125]. Because of its teratogenic potential, safe contraception and monthly pregnancy testing are required during and 1 month before and after therapy in women of childbearing age [52, 99, 103, 106, 112, 124].

Acitretin showed an average improvement in clinical score of up to 50% in clinical trials in patients with chronic hand eczema, with the best results in hyperkeratotic hand eczema [106, 126–129]. Thus, treatment with 30 mg/day can be considered effective and safe in patients with hyperkeratotic hand eczema [103, 104]. Nevertheless, this indication is an off-label use [112]. In women of childbearing age, the use of acitretin appears to be problematic in principle, as the continuation of safe contraception is required for at least 3 years after the end of therapy [124].

Systemic biologics

Dupilumab, a human monoclonal antibody, inhibits signaling of IL-4 and IL-13, both of which are key cytokines of Th2 inflammation [102, 130–132], and has no currently known additional immunosuppressive effects [133]. It is the first targeted biologic therapy approved for systemic treatment of moderate to severe atopic dermatitis [130, 134, 135]. Dupilumab also showed good efficacy in patients with atopic dermatitis and concomitant chronic hand eczema (in-label use) [103, 106, 136, 137]. In contrast, the current data, mainly from single case observations or small case series, on efficacy in allergic contact dermatitis (off-label use) is not yet conclusive [101, 136, 138–142]. Although allergic contact dermatitis is the manifestation of a Tc1/Th1-mediated response, some weaker allergens provoke Th2-mediated responses during the trigger phase [133, 136]. Given this theoretical background, IL-4 can also be seen as a potential key cytokine in the therapy of allergic contact dermatitis. Clinical trials are currently underway to investigate the efficacy of dupilumab in allergic contact dermatitis and chronic hand eczema [136].

For the following biologics, their use in recurrent contact dermatitis has not yet been studied or has not been well studied [101, 133]: infliximab (inhibits TNF-α), etanercept (inhibits TNF-α), adalimumab (inhibits TNF-α), omalizumab (selectively binds to IgE), secukinumab (inhibits IL-17A), ustekinumab (inhibits IL-12 and IL-23), rituximab (binds selectively to cluster of differentiation [CD] 20 surface antigen), and tralokinumab (inhibits IL-13 signaling).

Systemic immunosuppressants

Systemic immunosuppressants such as ciclosporin, azathioprine, and methotrexate (MTX) have traditionally been used for a variety of indications, either alone, in combination, or as glucocorticoid-sparing systemic therapeutics [102]. Their efficacy in contact dermatitis—an off-label use for all systemic immunosuppressants—has been insufficiently demonstrated.

Ciclosporin may be useful in chronic refractory hand eczema [106, 143–146]. Its in-label use is limited to atopic hand eczema [103, 112, 134, 147]. Off-label, ciclosporin may also be considered for non-atopic hand eczema in patients with a longer-term need for treatment at a maintenance dose of 3 mg/kg bw/day when first- and second-line therapy have been inadequate or are contraindicated [52, 99]. Blood pressure and serum creatinine should be monitored during ciclosporin therapy [102]. Ciclosporin should not be combined with phototherapy because of an increased risk of skin cancer [134].

There is evidence of efficacy for azathioprine in aerogenic contact dermatitis [148]. A randomized controlled trial has also been conducted for chronic hand eczema [149]. The efficacy and toxicity of azathioprine are related to the activity of the enzyme thiopurine methyltransferase [102]. Patients with normal enzyme activity (approximately 88% of the population) can receive a dose of azathioprine up to 1.5–2.5 mg/kg bw/day [150, 151]. Bone marrow toxicity and hepatotoxicity are the main side effects. Concomitant phototherapy is not recommended [134].

Methotrexate therapy has been reported in case series of patients with refractory hand eczema [150, 152]. Good results were obtained with initial doses between 5 and 20 mg weekly after 1–2 months of therapy.

Phototherapy

Various forms of phototherapy are classically used for contact dermatitis, especially chronic hand eczema [52, 99, 103, 106, 112, 153–159]. PUVA (in this case, topical psoralen plus UVA), UVB, and UVA1 have shown good results in chronic hand eczema and, together with topical glucocorticoids, are among the most important standard therapies [104, 106, 160–162]. For contact dermatitis in general, there is positive clinical experience with UVB broad spectrum and PUVA.

Phototherapy has a beneficial effect (the so-called hardening effect [102]) on the barrier function of the skin [163]. However, it may also have a carcinogenic effect. Long-term use or use as maintenance therapy should be avoided [102]. In general, phototherapy is not used in children and adolescents younger than 12 years of age because of the significant long-term hazard [164].

Phototherapy can be combined with other therapies, such as topical glucocorticoids or systemic retinoids, to accelerate their onset of action and reduce the total UV dose [154]. In contrast, combinations with topical calcineurin inhibitors as well as systemic immunosuppressants are not recommended due to increased skin carcinogenicity.

Antiseptic therapy

Topical antiseptics are used in cases of superinfected contact dermatitis or in cases of potential colonization with pathogenic microbial germs as the contact dermatitis-triggering factor [100, 102]. Therapeutic options include potassium permanganate solution, triclosan, chlorhexidine, polyhexanide, octenidine, or clioquinol.

Clioquinol cannot be recommended for use in infants and young children due to neurotoxicity [165]. In contrast, dyes (e.g., aqueous eosin disodium solution 0.5–2% new formulation formulary (NRF) 11.95, potassium permanganate solution concentrate 1% NRF 11.82) can find their use in irritant diaper eczema in children depending on the concentration of active ingredient used and the body surface to be treated.

Basic therapy

Basic therapy with skin care products to restore the skin barrier is an essential component in the treatment of contact dermatitis [102, 103, 166] including hand eczema [52, 99, 106]. It helps reduce inflammation and itching and has a glucocorticoid-sparing effect. It has also been shown in experimental studies to promote healing of irritant and allergic contact dermatitis without the need for other specific treatment [167, 168]. The basic therapy should be adapted to the eczema stage. Acute contact dermatitis is usually moist and should be treated with a hydrophilic preparation (gel, lotion, cream), whereas chronic stages tend to require a water-in-oil-based preparation (ointment).

Skin care products with inappropriate water and lipid content or allergenic ingredients may delay healing of contact dermatitis [101, 166, 169]. It should be noted that urea as a moisturizer has a significant irritant effect, especially in infants and young children [164]. Regarding recommendations for management in case of intolerance to components of bases or excipients, reference is made to the AWMF guideline "Use of preparations for topical application to the skin" [170].

Prevention

Various approaches can be taken to prevent contact dermatitis in general, particularly in occupational settings, such as automating processes to a large extent, eliminating the need for workers to expose their skin to irritants or allergens, replacing substances that are harmful to the skin with less irritant and less allergenic substances, and using potent allergens in closed systems (Table 5; [171, 172]).

Detailed recommendations on preventive measures at work are presented in the AWMF guidelines "Hand eczema, management" (registry number 013-053) and "Occupational skin remedies: skin protection, skin care and skin cleansing for the prevention of hand eczema" (registry number 013-056), which are currently under revision.

Table 5 Preventive measures according to the "STOP" principle for the reduction of skin-damaging activities. (Modified according to [207])

Measure		Examples
"S"	Substitution/ elimination	Replacement or prohibition of skin-damaging contact substances through regulations and legal provisions
"T"	Technical measures	Automation or encapsulation/shielding of processes to avoid contact
"O"	Organization measures	Distribution of skin-stressing activities among several persons; regular change of activities to reduce times with exposure to moisture and irritants
"P"	Personal measures	Health education/skin protection training; use of appropriate personal protective equipment (PPE; e.g., skin products, protective gloves)

Skin remedy

In order to generally prevent contact sensitization to ingredients of skin products, the products should not contain potent allergens. This may be the case with certain preservatives, fragrances, dyes, and plant ingredients [173–178].

Skin protection agents

Skin protectants are applied to dry clean skin before and several times during skin-stressing activities, where they form a thin physical "barrier layer." This is intended to reduce contact with irritants and allergens, stabilize the skin barrier when exposed to moisture, and facilitate the removal of soiling to reduce skin irritation caused by intensive washing [179–182]. Various in vitro and in vivo studies have shown that skin protectants can completely prevent or at least significantly reduce irritative effects of detergents [183–186]. In particular, skin protection products cannot replace suitable protective gloves when handling chemicals, solvents, or other hazardous substances.

Skin cleansers and skin disinfectants

Frequent washing with water and detergents leads to degreasing and drying of the skin and subsequently to irritant contact dermatitis. Mechanical skin cleansing with friction bodies in washing pastes or the use of brushes intensify the irritative effect [187]. For gentle skin cleansing, mild syndets (pH 5.5) should be used [180]. Alcohol-based skin disinfectants are available to reduce the frequency of washing in nursing and medical settings. These attack the skin barrier less than detergents [188, 189].

Skin care medium

Skin care products are used to support the regeneration of the skin at work and during leisure time after skin stress. They provide the skin with moisture and lipids, thereby preventing dehydration and the development of barrier disorders [180, 182, 190–192]. Various experimental and clinical studies have also shown that skin care products can prevent detergent-induced skin damage, and contribute to faster regeneration of barrier disorders and faster healing of irritative skin damage [167, 168, 193–195].

Protective gloves

Protective gloves protect against a wide variety of irritants, allergens, chemical and physical influences, pollution, and pathogens at work and during leisure time, and therefore play an important role in the prevention of contact dermatitis [196]. Glove materials and material thickness must be adapted to the respective contact substance exposures.

However, the wearing of protective gloves may itself become a notable risk factor for the development

of irritant and allergic contact dermatitis, contact urticaria, and anaphylactic reactions due to their occlusive effect and allergen content [187, 197–202]. As a rule, however, suitable alternative products are available for sensitized persons.

Professional conditionality

Occupational dermatoses as a totality of all possibly present occupational skin diseases, which are predominantly reported by means of "Dermatologist's Report—Initiation of Dermatological Procedure" (https://www.dguv.de/medien/formtexte/aerzte/f_6050/f6050.pdf, last accessed 28.01.2023), have been at the top of the annual reports for many years, with a large gap to other occupational diseases [203]. If there is reasonable suspicion of an occupational disease (BK) according to number 5101 of the annex to the Occupational Diseases Ordinance (BKV), the BK suspicion report (https://www.dguv.de/medien/formtexte/aerzte/f_6000/f6000.pdf, last accessed 28.01.2023) must be submitted and, in addition, a dermatologist's report must always be submitted in order to ensure that the *Berufsgenossenschaft* or accident insurance fund is informed in detail about the case of disease. During the course of treatment, both before and after recognition of BK 5101, a "Dermatologist's report—course of treatment" (https://www.dguv.de/medien/formtexte/aerzte/f_6052/f6052.pdf, last accessed 28.01.2023) must be submitted at intervals specified by the employers' liability insurance association or accident insurance fund. The main objective of the dermatologist's procedure, which has already been tried and tested since 1972, thus remains to achieve sustainable improvements for each affected insured person in terms of their disease severity, ability to work, quality of life, and prognosis [204].

Irritant contact dermatitis of the hands is the most frequently observed form of eczema among occupational dermatoses [205]. Wet work is considered to be the most significant occupational skin hazard. According to own epidemiological studies on a collective of employees with occupational dermatosis [205], the most frequent triggering contact substances were cleaning agents (for all occupations), disinfectants (mostly for health care workers), and chemicals in the form of acids and alkalis (mostly for hairdressers).

Allergic contact dermatitis of the hands is observed less frequently than irritant contact dermatitis in people working in occupations with high skin stress [203]. Thus, according to own epidemiological studies [205], allergic contact dermatitis was diagnosed more frequently than irritant contact dermatitis only among employees in the hairdressing trade, in floristry, and in the construction and electrical trades. In general, contact sensitization to rubber ingredients (here thiurams and N-isopropyl-N′-phenyl-p-phenylenediamine), epoxy resin, and p-phenylenediamine detected by patch testing showed the highest proportion of positive test reactions with occupational relevance [206].

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References

1. Dickel H, Bauer A, Brehler R, Mahler V, Merk HF, Neustädter I, et al. German S1 guideline: Contact dermatitis. J Dtsch Dermatol Ges. 2022;20:712–34.
2. Litchman G, Nair PA, Atwater AR, Bhutta BS. Contact dermatitis. Treasure Island: StatPearls; 2021.
3. Scheinman PL, Vocanson M, Thyssen JP, Johansen JD, Nixon RL, Dear K, et al. Contact dermatitis. Nat Rev Dis Primers. 2021;7:38.
4. Martin SF, Bonefeld CM. Mechanisms of irritant and allergic contact dermatitis. In: Johansen JD, Mahler V, Lepoittevin JP, Frosch PJ, editors. Contact dermatitis. Cham: Springer Nature; 2021. pp. 95–120.
5. Mahler V. Umweltassoziierte dermatologische Erkrankungen. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2017;60:605–17.
6. Mahler V. Kontaktekzeme. Akt Dermatol. 2014;40:95–107.
7. Gonçalo M. Phototoxic and photoallergic contact reactions. In: Johansen JD, Mahler V, Lepoittevin JP, Frosch PJ, editors. Contact dermatitis. Cham: Springer Nature; 2021. pp. 365–89.
8. de Groot AC. Patch testing: test concentrations and vehicles for 5200 chemicals. Wapserveen: acdegroot; 2022. p. 615.
9. Esser PR, Martin SF. Erweitertes Verständnis von Pathogenese und Therapie der Kontaktallergie. Hautarzt. 2020;71:174–81.
10. Karlberg AT, Börje A, Duus Johansen J, Lidén C, Rastogi S, Roberts D, et al. Activation of non-sensitizing or low-sensitizing fragrance substances into potent sensitizers—Prehaptens and prohaptens. Contact Derm. 2013;69:323–34.
11. Ott H, Bergström MA, Heise R, Skazik C, Zwadlo-Klarwasser G, Merk HF, et al. Cutaneous metabolic activation of carvoxime, a self-activating, skin-sensitizing prohapten. Chem Res Toxicol. 2009;22:399–405.
12. Sharma A, Saito Y, Hung SI, Naisbitt D, Uetrecht J, Bussiere J. The skin as a metabolic and immune-competent organ:

Implications for drug-induced skin rash. J Immunotoxicol. 2019;16:1–12.
13. Schmidt M, Raghavan B, Müller V, Vogl T, Fejer G, Tchaptchet S, et al. Crucial role for human Toll-like receptor 4 in the development of contact allergy to nickel. Nat Immunol. 2010;11:814–9.
14. Adam C, Wohlfarth J, Haussmann M, Sennefelder H, Rodin A, Maler M, et al. Allergy-inducing chromium compounds trigger potent innate immune stimulation via ROS-dependent inflammasome activation. J Invest Dermatol. 2017;137:367–76.
15. Sieben S, Kawakubo Y, Masaoudi TA, Merk HF, Blömeke B. Delayed-type hypersensitivity reaction to paraphenylenediamine is mediated by 2 different pathways of antigen recognition by specific alphabeta human T-cell clones. J Allergy Clin Immunol. 2002;109:1005–11.
16. Kohli N, Nedorost S. Inflamed skin predisposes to sensitization to less potent allergens. J Am Acad Dermatol. 2016;75:312–317.e1.
17. Blömeke B, Brans R, Dickel H, Bruckner T, Erdmann S, Heesen M, et al. Association between TNFA-308 G/A polymorphism and sensitization to para-phenylenediamine: a case-control study. Allergy. 2009;64:279–83.
18. Friedmann PS, Sanchez-Elsner T, Schnuch A. Genetic factors in susceptibility to contact sensitivity. Contact Derm. 2015;72:263–74.
19. Blömeke B, Brans R, Coenraads PJ, Dickel H, Bruckner T, Hein DW, et al. Para-phenylenediamine and allergic sensitization: risk modification by N-acetyltransferase 1 and 2 genotypes. Br J Dermatol. 2009;161:1130–5.
20. Werfel T, Allam JP, Biedermann T, Eyerich K, Gilles S, Guttman-Yassky E, et al. Cellular and molecular immunologic mechanisms in patients with atopic dermatitis. J Allergy Clin Immunol. 2016;138:336–49.
21. Molin S, Vollmer S, Weiss EH, Ruzicka T, Prinz JC. Filaggrin mutations may confer susceptibility to chronic hand eczema characterized by combined allergic and irritant contact dermatitis. Br J Dermatol. 2009;161:801–7.
22. Thyssen JP, Linneberg A, Ross-Hansen K, Carlsen BC, Meldgaard M, Szecsi PB, et al. Filaggrin mutations are strongly associated with contact sensitization in individuals with dermatitis. Contact Derm. 2013;68:273–6.
23. Goossens A, Amaro C, Mahler V. Protein contact dermatitis. In: Johansen JD, Mahler V, Lepoittevin JP, Frosch PJ, editors. Contact dermatitis. Cham: Springer Nature; 2021. pp. 355–64.
24. Skudlik C, Allmers H, John SM, Becker D, Dickel H, Geier J, et al. Beurteilung der Auswirkungen einer Allergie gegenüber Naturgummilatex bei der Minderung der Erwerbsfähigkeit im Rahmen der BK 5101. Dermatol Beruf Umwelt. 2010;58:54–60.
25. Dickel H. Aussergewöhnliche Berufsallergien durch Nahrungsmittel tierischen Ursprungs. Hautarzt. 2021;72:493–501.
26. Veien NK. Clinical features of contact dermatitis. In: Johansen JD, Mahler V, Lepoittevin JP, Frosch PJ, editors. Contact dermatitis. Cham: Springer Nature; 2021. pp. 241–94.
27. Pastor-Nieto MA, Giménez-Arnau AM. Immediate and delayed hypersensitivity reactions occurring in the kitchen: hazards related to being a chef or kitchen staff. In: John SM, Johansen JD, Rustemeyer T, Elsner P, Maibach HI, editors. Kanerva's occupational dermatology. Cham: Springer Nature; 2020. pp. 1223–59.
28. Susitaival P. Animals. In: John SM, Johansen JD, Rustemeyer T, Elsner P, Maibach HI, editors. Kanerva's occupational dermatology. Cham: Springer Nature; 2020. pp. 1089–98.
29. Levin C, Warshaw E. Protein contact dermatitis: allergens, pathogenesis, and management. Dermatitis. 2008;19:241–51.
30. Cashman MW, Reutemann PA, Ehrlich A. Contact dermatitis in the United States: epidemiology, economic impact, and workplace prevention. Dermatol Clin. 2012;30:87–98.
31. Coenraads PJ, Gonçalo M. Skin diseases with high public health impact. Contact dermatitis. Eur J Dermatol. 2007;17:564–5.
32. Bains SN, Nash P, Fonacier L. Irritant contact dermatitis. Clin Rev Allergy Immunol. 2019;56:99–109.
33. Diepgen TL, Ofenloch RF, Bruze M, Bertuccio P, Cazzaniga S, Coenraads PJ, et al. Prevalence of contact allergy in the general population in different European regions. Br J Dermatol. 2016;174:319–29.
34. Thyssen JP, Johansen JD, Linneberg A, Menné T. The epidemiology of hand eczema in the general population—Prevalence and main findings. Contact Derm. 2010;62:75–87.
35. Hermann-Kunz E. Allergische Krankheiten in Deutschland. Ergebnisse einer repräsentativen Studie. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2000;43:400–6.
36. Admani S, Jacob SE. Allergic contact dermatitis in children: review of the past decade. Curr Allergy Asthma Rep. 2014;14:421.
37. Alinaghi F, Bennike NH, Egeberg A, Thyssen JP, Johansen JD. Prevalence of contact allergy in the general population: A systematic review and meta-analysis. Contact Derm. 2019;80:77–85.
38. Prakash AV, Davis MD. Contact dermatitis in older adults: a review of the literature. Am J Clin Dermatol. 2010;11:373–81.
39. Simonsen AB, Deleuran M, Johansen JD, Sommerlund M. Contact allergy and allergic contact dermatitis in children—A review of current data. Contact Derm. 2011;65:254–65.
40. Schmitz R, Thamm M, Ellert U, Kalcklösch M, Schlaud M, KiGGS Study Group.. Verbreitung häufiger Allergien bei Kindern und Jugendlichen in Deutschland: Ergebnisse der KiGGS-Studie – Erste Folgebefragung (KiGGS Welle 1). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2014;57:771–8.
41. Ward DB, Fleischer AB Jr., Feldman SR, Krowchuk DP. Characterization of diaper dermatitis in the United States. Arch Pediatr Adolesc Med. 2000;154:943–6.
42. Schnuch A, Uter W, Geier J, Gefeller O. Epidemiology of contact allergy: an estimation of morbidity employing the clinical epidemiology and drug-utilization research (CE-DUR) approach. Contact Derm. 2002;47:32–9.
43. Mahler V, Glöckler A, Worm M, Spornraft-Ragaller P, Bauer A, Dickel H, et al. Proteinkontaktdermatitis. Allergologie. 2013;36:219–26.
44. Jeebhay MF, Robins TG, Lehrer SB, Lopata AL. Occupational seafood allergy: a review. Occup Environ Med. 2001;58:553–62.
45. Lantinga H, Nater JP, Coenraads PJ. Prevalence, incidence and course of eczema on the hands and forearms in a sample of the general population. Contact Derm. 1984;10:135–9.
46. Berndt U, Hinnen U, Iliev D, Elsner P. Role of the atopy score and of single atopic features as risk factors for the development of hand eczema in trainee metal workers. Br J Dermatol. 1999;140:922–4.
47. Diepgen TL, Fartasch M, Hornstein OP. Kriterien zur Beurteilung der atopischen Hautdiathese. Dermatol Beruf Umwelt. 1991;39:79–83.

48. Diepgen TL, Sauerbrei W, Fartasch M. Development and validation of diagnostic scores for atopic dermatitis incorporating criteria of data quality and practical usefulness. J Clin Epidemiol. 1996;49:1031–8.
49. Molin S, Ruzicka T, Herzinger T. Smoking is associated with combined allergic and irritant hand eczema, contact allergies and hyperhidrosis. J Eur Acad Dermatol Venereol. 2015;29:2483–6.
50. Nosbaum A, Vocanson M, Rozieres A, Hennino A, Nicolas JF. Allergic and irritant contact dermatitis. Eur J Dermatol. 2009;19:325–32.
51. Agner T, Elsner P. Hand eczema: epidemiology, prognosis and prevention. J Eur Acad Dermatol Venereol. 2020;34(Suppl 1):4–12.
52. Thyssen JP, Schuttelaar MLA, Alfonso JH, Andersen KE, Angelova-Fischer I, Arents BWM, et al. Guidelines for diagnosis, prevention, and treatment of hand eczema. Contact Derm. 2022;86:357–78.
53. Geier J, Struppek K. Anamnese-Auxilium für die berufsdermatologische Untersuchung von Maurern, Betonbauern, Fliesenlegern und Angehörigen verwandter Berufe. Derm Beruf Umwelt. 1995;43:75–80.
54. Geier J, Brehler R, Eck E, Koch P, Peters K-P, Rakoski J, et al. Berufsspezifische Epikutantestung bei Maurern und Angehörigen verwandter Berufe. Empfehlungen der Arbeitsgruppe „Berufs-Testreihen" der Deutschen Kontaktallergie-Gruppe. Dermatol Beruf Umwelt. 1999;47:29–33.
55. 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. Dermatol Beruf Umwelt. 2006;54:47–52.
56. Koch P, Brehler R, Eck E, Geier J, Hillen U, Peters KP, et al. Berufsspezifische Epikutantestung für Angehörige der Heil- und Pflegeberufe. Dermatol Beruf Umwelt. 2002;50:155–62.
57. Proske S, Brehler R, Dickel H, Eck E, Geier J, Hillen U, et al. Berufsspezifische Epikutantestung in der Altenpflege: Empfehlungen der Arbeitsgruppe „Berufs-Testreihen" der Deutschen Kontaktallergie-Gruppe. Dermatol Beruf Umwelt. 2005;53:50–3.
58. Uter W, Wulfhorst B, Pilz B, Raguz J. Anamnese-Auxilium für das Friseurgewerbe – Dermatologiosches Risikoprofil. Dermatol Beruf Umwelt. 1997;45:165–9.
59. Uter W. Epidemiologie und Prävention von Handekzemen in Feuchtberufen am Beispiel des Friseurhandwerks. Osnabrück: Universitätsverlag Rasch; 1999.
60. Wessbecher R, Straube M, Szliska C, Schwanitz HJ. Anamneseauxilium und gewerbedermatologische Beurteilung bei medizinischen Bademeistern, Masseuren und Physiotherapeuten. Hautarzt. 1998;49:912–9.
61. Dickel H, Mahler V. Leitliniengerechte Diagnostik der Kontaktallergie in der Praxis. Hautarzt. 2020;71:182–9.
62. Schlaud M, Atzpodien K, Thierfelder W. Allergische Erkrankungen. Ergebnisse aus dem Kinder- und Jugendgesundheitssurvey (KiGGS). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2007;50:701–10.
63. de Waard-van der Spek FB, Darsow U, Mortz CG, Orton D, Worm M, Muraro A, et al. EAACI position paper for practical patch testing in allergic contact dermatitis in children. Pediatr Allergy Immunol. 2015;26:598–606.
64. Worm M, Aberer W, Agathos M, Becker D, Brasch J, Fuchs T, et al. Patch testing in children—recommendations of the German Contact Dermatitis Research Group (DKG). J Dtsch Dermatol Ges. 2007;5:107–9.
65. 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;17:1076–93.
66. 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;17:1187–207.
67. Mahler V, Dickel H. Wichtigste Kontaktallergene beim Handekzem. Hautarzt. 2019;70:778–89.
68. Aalto-Korte K, Suuronen K, Frosch PJ. Patch testing with the patients' own products. In: Johansen JD, Mahler V, Lepoittevin JP, Frosch PJ, editors. Contact dermatitis. Cham: Springer Nature; 2021. pp. 551–69.
69. Dickel H, Taylor JS, Evey P, Merk HF. Delayed readings of a standard screening patch test tray: frequency of "lost," "found," and "persistent" reactions. Am J Contact Dermat. 2000;11:213–7.
70. Forkel S, Schubert S, Dickel H, Gina M, Schröder-Kraft C, Vieluf D, et al. The benefit of late readings in patch testing depends both on allergen and patient characteristics. Allergy. 2022;77:1477–85.
71. Dickel H, Kreft B, Kuss O, Worm M, Soost S, Brasch J, et al. Increased sensitivity of patch testing by standardized tape stripping beforehand: a multicenter diagnostic accuracy study. Contact Derm. 2010;62:294–302.
72. Dickel H, Altmeyer P, Brasch J. "New" techniques for more sensitive patch testing? J Dtsch Dermatol Ges. 2011;9:889–96.
73. Dickel H, Kreft B, Geier J. Strip patch testing does not affect reaction profiles of standard allergens. Contact Derm. 2015;73:36–43.
74. Dickel H, Geier J, Kreft B, Pfützner W, Kuss O. Comparing reliabilities of strip and conventional patch testing. Contact Derm. 2017;76:342–9.
75. Dickel H, Kamphowe J, Geier J, Altmeyer P, Kuss O. Strip patch test vs. conventional patch test: investigation of dose-dependent test sensitivities in nickel- and chromium-sensitive subjects. J Eur Acad Dermatol Venereol. 2009;23:1018–25.
76. Spier HW, Sixt I. Untersuchungen über die Abhängigkeit des Ausfalles der Ekzem-Läppchenproben von der Hornschichtdicke. Quantitativer Abriß-Epikutantest. Hautarzt. 1955;6:152–9.
77. Dickel H, Bruckner TM, Erdmann SM, Fluhr JW, Frosch PJ, Grabbe J, et al. The "strip" patch test: Results of a multicentre study towards a standardization. Arch Dermatol Res. 2004;296:212–9.
78. Hannuksela M, Salo H. The repeated open application test (ROAT). Contact Derm. 1986;14:221–7.
79. Johansen JD, Bruze M, Andersen KE, Frosch PJ, Dreier B, White IR, et al. The repeated open application test: suggestions for a scale of evaluation. Contact Derm. 1998;39:95–6.
80. Johansen JD, Frosch PJ, Menné T. Allergic contact dermatitis in humans: experimental and quantitative aspects. In: Johansen JD, Frosch PJ, Lepoittevin JP, editors. Contact dermatitis. Heidelberg: Springer; 2011. pp. 241–51.
81. Geier J, Bauer A, Becker D, Brehler R, Breit R, Dickel H, et al. Empfehlungen der Arbeitsgruppe „Photopatchtest" der Deutschen Kontaktallergie-Gruppe (DKG) zur Durchführung des Photopatchtests. J Dtsch Dermatol Ges. 2018;16:1363–4.
82. Gonçalo M. Photopatch testing. In: Johansen JD, Mahler V, Lepoittevin JP, Frosch PJ, editors. Contact dermatitis. Cham: Springer Nature; 2021. pp. 593–608.
83. Goncalo M, Ferguson J, Bonevalle A, Bruynzeel DP, Gimenez-Arnau A, Goossens A, et al. Photopatch testing:

recommendations for a European photopatch test baseline series. Contact Derm. 2013;68:239–43.
84. Lehmann P. Diagnostic approach to photodermatoses. J Dtsch Dermatol Ges. 2006;4:965–75.
85. Robert Koch-Institut (RKI), Klein R, Idel H, Lehmann I. Diagnostische Relevanz des Lymphozytentransformationstestes in der Umweltmedizin. Mitteilung der Kommission „Methoden und Qualitätssicherung in der Umweltmedizin“ am Robert Koch-Institut (RKI). Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz. 2002;45:745–9.
86. Renz H, Biedermann T, Bufe A, Eberlein B, Jappe U, Ollert M, et al. In-vitro-Allergiediagnostik. Leitlinie der Deutschen Gesellschaft für Allergologie und klinische Immunologie (DGAKI) unter Beteiligung des Ärzteverbandes Deutscher Allergologen (ÄDA), der Gesellschaft für Pädiatrische Allergologie und Umweltmedizin (GPA) und der Deutschen Dermatologische Gesellschaft (DDG). Allergo J. 2010;19:110–28.
87. Slodownik D, Lee A, Nixon R. Irritant contact dermatitis: a review. Australas J Dermatol. 2008;49:1–9. quiz 10–1.
88. John SM, Bartel G, Brehler R, Degenhardt A, Fluhr J, Frosch PJ, et al. Negativliste: Hautirritabilitäts- und Hautfunktionsdiagnostik zur Erfassung und Bewertung irritativer Hautschäden. ABD-Arbeitsgruppe „Erfassung und Bewertung irritativer Hautschäden“. Dermatol Beruf Umwelt. 2006;54:108–11.
89. Doutre M-S. Occupational contact urticaria and protein contact dermatitis. Eur J Dermatol. 2005;15:419.
90. Mørtz CG, Bindslev-Jensen C. Skin tests for immediate hypersensitivity. In: Johansen JD, Mahler V, Lepoittevin JP, Frosch PJ, editors. Contact Dermatitis. Cham: Springer Nature; 2021. pp. 609–17.
91. Li BS, Ale IS, Maibach HI. Contact urticaria syndrome: Occupational aspects. In: John SM, Johansen JD, Rustemeyer T, Elsner P, Maibach HI, editors. Kanerva's occupational dermatology. Cham: Springer Nature; 2020. pp. 2595–628.
92. Ruëff F, Bergmann KC, Brockow K, Fuchs T, Grübl A, Jung K, et al. Hauttests zur Diagnostik von allergischen Sofort-typreaktionen. Allergo J. 2010;19:402–15.
93. Mahler V. Prick and intracutaneous testing and IgE testing. In: John SM, Johansen JD, Rustemeyer T, Elsner P, Maibach HI, editors. Kanerva's occupational dermatology. Cham: Springer Nature; 2020. pp. 1317–45.
94. Vester L, Thyssen JP, Menné T, Johansen JD. Occupational food-related hand dermatoses seen over a 10-year period. Contact Derm. 2012;66:264–70.
95. Garzorz-Stark N, Eyerich K. Molekulare Diagnostik des Handekzems. Hautarzt. 2019;70:760–5.
96. Bentz P, Eyerich K, Weisshaar E. Psoriasis or eczema? One-year results from the DGUV research project FB323 with application of the molecular classifier in occupational dermatoses. J Dtsch Dermatol Ges. 2022;20:1233–4.
97. Wiegand C, Bauer A, Brasch J, Nenoff P, Schaller M, Mayser P, et al. Are the classic diagnostic methods in mycology still state of the art? J Dtsch Dermatol Ges. 2016;14:490–4.
98. Fölster-Holst R. Differential diagnoses of diaper dermatitis. Pediatr Dermatol. 2018;35(Suppl 1):s10–s8.
99. Diepgen TL, Elsner P, Schliemann S, Fartasch M, Köllner A, Skudlik C, et al. Management von Handekzemen – Leitlinie – LCD-10-Ziffer: L20. L23. L24. L25. L30. J Dtsch Dermatol Ges. 2009;7(Suppl. 3):S1–S16.
100. Weyandt G, Breitkopf C, Werner RN, Zidane M, Furtwängler A, Jongen J, et al. German S1 guidelines for the diagnosis and treatment of perianal dermatitis (anal eczema). J Dtsch Dermatol Ges. 2020;18:648–57.
101. Brar KK. A review of contact dermatitis. Ann Allergy Asthma Immunol. 2021;126:32–9.
102. Ludriksone L, Antonov D, Schliemann S, Elsner P. Therapy of allergic and irritant contact dermatitis. In: Johansen JD, Mahler V, Lepoittevin JP, Frosch PJ, editors. Contact dermatitis. Cham: Springer Nature; 2021. pp. 1273–97.
103. Elsner P, Agner T. Hand eczema: treatment. J Eur Acad Dermatol Venereol. 2020;34(Suppl 1):13–21.
104. Schuttelaar MLA, Oosterhaven JAF, Christoffers WA, Romeijn GLE, Voorberg AN. Evidence-based management of hand eczema. In: John SM, Johansen JD, Rustemeyer T, Elsner P, Maibach HI, editors. Kanerva's occupational dermatology. Cham: Springer Nature; 2020. pp. 1399–416.
105. Spiewak R. Immunotherapy of allergic contact dermatitis. Immunotherapy. 2011;3:979–96.
106. Berthold E, Weisshaar E. Therapie des Handekzems. Hautarzt. 2019;70:790–6.
107. Kraft M, Soost S, Worm M. Topical and systemic corticosteroids. In: John SM, Johansen JD, Rustemeyer T, Elsner P, Maibach HI, editors. Kanerva's occupational dermatology. Cham: Springer Nature; 2020. pp. 1433–44.
108. Luger T, Loske KD, Elsner P, Kapp A, Kerscher M, Korting HC, et al. Topische Dermatotherapie mit Glukokortikoiden – Therapeutischer Index. J Dtsch Dermatol Ges. 2004;2:629–34.
109. Egeberg A, Schwarz P, Harsløf T, Andersen YMF, Pottegård A, Hallas J, et al. Association of potent and very potent topical corticosteroids and the risk of osteoporosis and major osteoporotic fractures. JAMA Dermatol. 2021;157:275–82.
110. Jackson RD. Topical corticosteroids and glucocorticoid-induced osteoporosis-cumulative dose and duration matter. JAMA Dermatol. 2021;157:269–70.
111. Veien NK, Olholm Larsen P, Thestrup-Pedersen K, Schou G. Long-term, intermittent treatment of chronic hand eczema with mometasone furoate. Br J Dermatol. 1999;140:882–6.
112. Diepgen TL, Andersen KE, Chosidow O, Coenraads PJ, Elsner P, English J, et al. Guidelines for diagnosis, prevention and treatment of hand eczema. J Dtsch Dermatol Ges. 2015;13:e1–e22.
113. Isaksson M. Corticosteroids. Dermatol Ther. 2004;17:314–20.
114. Foti C, Bonifazi E, Casulli C, Bonamonte D, Conserva A, Angelini G. Contact allergy to topical corticosteroids in children with atopic dermatitis. Contact Derm. 2005;52:162–3.
115. Soost S, Worm M. Therapie berufsbedingter Hauterkrankungen. Hautarzt. 2009;60:718–21.
116. Luger T, Paul C. Potential new indications of topical calcineurin inhibitors. Dermatology. 2007;215(Suppl 1):45–54.
117. Aschoff R, Schmitt J, Knuschke P, Koch E, Bräutigam M, Meurer M. Evaluation of the atrophogenic potential of hydrocortisone 1 % cream and pimecrolimus 1 % cream in uninvolved forehead skin of patients with atopic dermatitis using optical coherence tomography. Exp Dermatol. 2011;20:832–6.
118. Mose KF, Andersen F, Røpke MA, Skov L, Friedmann PS, Andersen KE. Anti-inflammatory potency testing of topical corticosteroids and calcineurin inhibitors in human volunteers sensitized to diphenylcyclopropenone. Br J Clin Pharmacol. 2018;84:1719–28.
119. Queille-Roussel C, Graeber M, Thurston M, Lachapelle JM, Decroix J, de Cuyper C, et al. SDZ ASM 981 is the first non-steroid that suppresses established nickel contact dermatitis elicited by allergen challenge. Contact Derm. 2000;42:349–50.
120. Engel K, Reuter J, Seiler C, Schulte Monting J, Jakob T, Schempp CM. Anti-inflammatory effect of pimecrolimus

in the sodium lauryl sulphate test. J Eur Acad Dermatol Venereol. 2008;22:447–50.
121. Grassberger M, Steinhoff M, Schneider D, Luger TA. Pimecrolimus—an anti-inflammatory drug targeting the skin. Exp Dermatol. 2004;13:721–30.
122. Schliemann S, Kelterer D, Bauer A, John SM, Skudlik C, Schindera I, et al. Tacrolimus ointment in the treatment of occupationally induced chronic hand dermatitis. Contact Derm. 2008;58:299–306.
123. Worm M, Bauer A, Elsner P, Mahler V, Molin S, Nielsen TSS. Efficacy and safety of topical delgocitinib in patients with chronic hand eczema: data from a randomized, double-blind, vehicle-controlled phase IIa study. Br J Dermatol. 2020;182:1103–10.
124. Molin SC, Ruzicka T. Retinoids. In: John SM, Johansen JD, Rustemeyer T, Elsner P, Maibach HI, editors. Kanerva's occupational dermatology. Cham: Springer Nature; 2020. pp. 1417–31.
125. Bissonnette R, Worm M, Gerlach B, Guenther L, Cambazard F, Ruzicka T, et al. Successful retreatment with alitretinoin in patients with relapsed chronic hand eczema. Br J Dermatol. 2010;162:420–6.
126. Song M, Lee H-J, Lee W-K, Kim H-S, Ko H-C, Kim M-B, et al. Acitretin as a therapeutic option for chronic hand eczema. Ann Dermatol. 2017;29:385–7.
127. Politiek K, Christoffers WA, Coenraads PJ, Schuttelaar MLA. Alitretinoin and acitretin in severe chronic hand eczema; results from a retrospective daily practice study. Dermatol Ther. 2016;29:364–71.
128. Tan J, Maari C, Nigen S, Bolduc C, Bissonnette R. Open-label exploratory study of acitretin for the treatment of severe chronic hand dermatitis. J Dermatolog Treat. 2015;26:373–5.
129. Thestrup-Pedersen K, Andersen KE, Menné T, Veien NK. Treatment of hyperkeratotic dermatitis of the palms (eczema keratoticum) with oral acitretin. A single-blind placebo-controlled study. Acta Derm Venereol. 2001;81:353–5.
130. Jappe U, Beckert H, Bergmann KC, Gülsen A, Klimek L, Philipp S, et al. Biologics for atopic diseases: Indication, side effect management, and new developments. Allergol Sel. 2021;5:1–25.
131. Moyle M, Cevikbas F, Harden JL, Guttman-Yassky E. Understanding the immune landscape in atopic dermatitis: The era of biologics and emerging therapeutic approaches. Exp Dermatol. 2019;28:756–68.
132. Gooderham MJ, Hong HC, Eshtiaghi P, Papp KA. Dupilumab: A review of its use in the treatment of atopic dermatitis. J Am Acad Dermatol. 2018;78(Suppl 1):S28–S36.
133. Bhatia J, Sarin A, Wollina U, Lotti T, Navarini AA, Mueller SM, et al. Review of biologics in allergic contact dermatitis. Contact Derm. 2020;83:179–81.
134. Werfel T, Heratizadeh A, Aberer W, Ahrens F, Augustin M, Biedermann T, et al. Update "Systemic treatment of atopic dermatitis" of the S2k-guideline on atopic dermatitis. J Dtsch Dermatol Ges. 2021;19:151–68.
135. Shirley M. Dupilumab: first global approval. Drugs. 2017;77:1115–21.
136. Hendricks AJ, Yosipovitch G, Shi VY. Dupilumab use in dermatologic conditions beyond atopic dermatitis—A systematic review. J Dermatolog Treat. 2021;32:19–28.
137. Oosterhaven JAF, Voorberg AN, Romeijn GLE, de Bruin-Weller MS, Schuttelaar MLA. Effect of dupilumab on hand eczema in patients with atopic dermatitis: An observational study. J Dermatol. 2019;46:680–5.
138. Crepy MN, Nosbaum A, Bensefa-Colas L. Blocking type 2 inflammation by dupilumab does not control classic (type 1-driven) allergic contact dermatitis in chronic hand eczema. Contact Derm. 2019;81:145–7.
139. Machler BC, Sung CT, Darwin E, Jacob SE. Dupilumab use in allergic contact dermatitis. J Am Acad Dermatol. 2019;80:280–1.
140. Chipalkatti N, Lee N, Zancanaro P, Dumont N, Donovan C, Rosmarin D. Dupilumab as a treatment for allergic contact dermatitis. Dermatitis. 2018;29:347–8.
141. Goldminz AM, Scheinman PL. A case series of dupilumab-treated allergic contact dermatitis patients. Dermatol Ther. 2018;31:e12701.
142. Joshi SR, Khan DA. Effective use of dupilumab in managing systemic allergic contact dermatitis. Dermatitis. 2018;29:282–4.
143. Granlund H, Erkko P, Reitamo S. Long-term follow-up of eczema patients treated with cyclosporine. Acta Derm Venereol. 1998;78:40–3.
144. Granlund H, Erkko P, Reitamo S. Comparison of the influence of cyclosporine and topical betamethasone-17,21-dipropionate treatment on quality of life in chronic hand eczema. Acta Derm Venereol. 1997;77:54–8.
145. Granlund H, Erkko P, Eriksson E, Reitamo S. Comparison of cyclosporine and topical betamethasone-17,21-dipropionate in the treatment of severe chronic hand eczema. Acta Derm Venereol. 1996;76:371–6.
146. Reitamo S, Granlund H. Cyclosporin A in the treatment of chronic dermatitis of the hands. Br J Dermatol. 1994;130:75–8.
147. Schmitt J, Schmitt N, Meurer M. Cyclosporin in the treatment of patients with atopic eczema—A systematic review and meta-analysis. J Eur Acad Dermatol Venereol. 2007;21:606–19.
148. Verma KK, Mahesh R, Srivastava P, Ramam M, Mukhopadhyaya AK. Azathioprine versus betamethasone for the treatment of parthenium dermatitis: a randomized controlled study. Indian J Dermatol Venereol Leprol. 2008;74:453–7.
149. Agarwal US, Besarwal RK. Topical clobetasol propionate 0.05 % cream alone and in combination with azathioprine in patients with chronic hand eczema: an observer blinded randomized comparative trial. Indian J Dermatol Venereol Leprol. 2013;79:101–3.
150. da Mota R, Homey B. Treatment of chronic hand eczema: other immunomodulating therapies. In: John SM, Johansen JD, Rustemeyer T, Elsner P, Maibach HI, editors. Kanerva's Occupational Dermatology. Cham: Springer Nature; 2020. pp. 1445–50.
151. Wise M, Callen JP. Azathioprine: a guide for the management of dermatology patients. Dermatol Ther. 2007;20:206–15.
152. Egan CA, Rallis TM, Meadows KP, Krueger GG. Low-dose oral methotrexate treatment for recalcitrant palmoplantar pompholyx. J Am Acad Dermatol. 1999;40:612–4.
153. Tzaneva S, Kittler H, Thallinger C, Hönigsmann H, Tanew A. Oral vs. bath PUVA using 8-methoxypsoralen for chronic palmoplantar eczema. Photodermatol Photoimmunol Photomed. 2009;25:101–5.
154. Stege H. Ultravioletttherapie des chronischen Handekzems. Hautarzt. 2008;59:696–702.
155. Warshaw E, Lee G, Storrs FJ. Hand dermatitis: a review of clinical features, therapeutic options, and long-term outcomes. Am J Contact Dermat. 2003;14:119–37.
156. Gritiyarangsan P, Sukhum A, Tresukosol P, Kullavanijaya P. Topical PUVA therapy for chronic hand eczema. J Dermatol. 1998;25:299–301.
157. Sjövall P, Christensen OB. Treatment of chronic hand eczema with UV-B Handylux in the clinic and at home. Contact Derm. 1994;31:5–8.

158. Sjövall P, Christensen OB. Local and systemic effect of ultraviolet irradiation (UVB and UVA) on human allergic contact dermatitis. Acta Derm Venereol. 1986;66:290–4.
159. Mørk NJ, Austad J. Short-wave ultraviolet light (UVB) treatment of allergic contact dermatitis of the hands. Acta Derm Venereol. 1983;63:87–9.
160. Sezer E, Etikan I. Local narrowband UVB phototherapy vs. local PUVA in the treatment of chronic hand eczema. Photodermatol Photoimmunol Photomed. 2007;23:10–4.
161. Petering H, Breuer C, Herbst R, Kapp A, Werfel T. Comparison of localized high-dose UVA1 irradiation versus topical cream psoralen-UVA for treatment of chronic vesicular dyshidrotic eczema. J Am Acad Dermatol. 2004;50:68–72.
162. Schmidt T, Abeck D, Boeck K, Mempel M, Ring J. UVA1 irradiation is effective in treatment of chronic vesicular dyshidrotic hand eczema. Acta Derm Venereol. 1998;78:318–9.
163. Bauer A, Kelterer D, Bartsch R, Schlegel A, Pearson J, Stadeler M, et al. Prevention of hand dermatitis in bakers' apprentices: different efficacy of skin protection measures and UVB hardening. Int Arch Occup Environ Health. 2002;75:491–9.
164. Werfel T, Aberer W, Ahrens F, Augustin M, Biedermann T, Diepgen T, et al. Leitlinie Neurodermitis [atopisches Ekzem; atopische Dermatitis]. J Dtsch Dermatol Ges. 2016;14:e1–e75.
165. American Academy of Pediatrics Committee on Drugs. Clioquinol (iodochlorhydroxyquin, vioform) and iodoquinol (diiodohydroxyquin): blindness and neuropathy. Pediatrics. 1990;86:797–8.
166. Agner T, Jungersted JM. Emollients: effects, evidence, and side effects. In: John SM, Johansen JD, Rustemeyer T, Elsner P, Maibach HI, editors. Kanerva's occupational dermatology. Cham: Springer Nature; 2020. pp. 1451–9.
167. De Paépe K, Hachem JP, Vanpee E, Goossens A, Germaux MA, Lachapelle JM, et al. Beneficial effects of a skin tolerance-tested moisturizing cream on the barrier function in experimentally-elicited irritant and allergic contact dermatitis. Contact Derm. 2001;44:337–43.
168. Ramsing DW, Agner T. Preventive and therapeutic effects of a moisturizer. An experimental study of human skin. Acta Derm Venereol. 1997;77:335–7.
169. Lynde CW. Moisturizers: what they are and how they work. Skin Therapy Lett. 2001;6:3–5.
170. Wohlrab J, Staubach P, Augustin M, Eisert L, Hünerbein A, Nast A, et al. S2k guidelines for the use of topical preparations on the skin. J Dtsch Dermatol Ges. 2018;16:376–92.
171. Bauer A, Rönsch H, Elsner P, Dittmar D, Bennett C, Schuttelaar MLA, et al. Interventions for preventing occupational irritant hand dermatitis. Cochrane Database Syst Rev. 2018;4:CD4414.
172. Lachapelle J-M. Principles of prevention and protection in contact dermatitis (with special reference to occupational dermatology). In: Rycroft RJG, Menné T, Frosch PJ, Lepoittevin JP, editors. Textbook of contact dermatitis. Berlin: Springer; 2001. pp. 979–93.
173. Bruusgaard-Mouritsen MA, Johansen JD, Zachariae C, Kirkeby CS, Garvey LH. Natural ingredients in cosmetic products—A suggestion for a screening series for skin allergy. Contact Derm. 2020;83:251–70.
174. Dinkloh A, Worm M, Geier J, Schnuch A, Wollenberg A. Contact sensitization in patients with suspected cosmetic intolerance: results of the IVDK 2006–2011. J Eur Acad Dermatol Venereol. 2015;29:1071–81.
175. Nguyen HL, Yiannias JA. Contact dermatitis to medications and skin products. Clin Rev Allergy Immunol. 2019;56:41–59.
176. Uter W, Geier J, Lessmann H, Schnuch A. Inhaltsstoffe von Hautschutz- und -pflegemitteln aus allergologischer Sicht. Analyse von IVDK-Daten und Literaturübersicht. Dermatol Beruf Umwelt. 2005;53:172–82.
177. Wetter DA, Yiannias JA, Prakash AV, Davis MD, Farmer SA, el-Azhary RA. Results of patch testing to personal care product allergens in a standard series and a supplemental cosmetic series: an analysis of 945 patients from the Mayo Clinic Contact Dermatitis Group, 2000–2007. J Am Acad Dermatol. 2010;63:789–98.
178. Rodriguez-Homs LG, Atwater AR. Allergens in medical hand skin cleansers. Dermatitis. 2019;30:336–41.
179. Agner T, Held E. Skin protection programmes. Contact Derm. 2002;47:253–6.
180. Fartasch M, Diepgen TL, Drexler H, Elsner P, John SM, Schliemann S. S1-Leitlinie „Berufliche Hautmittel: Hautschutz, Hautpflege und Hautreinigung" (ICD 10: L23, L24) – Kurzversion. J Dtsch Dermatol Ges. 2015;13:594–607.
181. Kütting B, Drexler H. Der dreistufige Hautschutzplan. Ein wirksames Instrument der Primärprävention oder eher geeignet für die Sekundärprävention? Dtsch Med Wochenschr. 2008;133:201–5.
182. Mathias CG. Prevention of occupational contact dermatitis. J Am Acad Dermatol. 1990;23:742–8.
183. Frosch PJ, Kurte A. Efficacy of skin barrier creams (IV). The repetitive irritation test (RIT) with a set of 4 standard irritants. Contact Derm. 1994;31:161–8.
184. Kresken J, Klotz A. Occupational skin-protection products—A review. Int Arch Occup Environ Health. 2003;76:355–8.
185. Wigger-Alberti W, Caduff L, Burg G, Elsner P. Experimentally induced chronic irritant contact dermatitis to evaluate the efficacy of protective creams in vivo. J Am Acad Dermatol. 1999;40:590–6.
186. Zhai H, Maibach HI. Effect of barrier creams: human skin in vivo. Contact Derm. 1996;35:92–6.
187. Hamnerius N, Svedman C, Bergendorff O, Björk J, Bruze M, Pontén A. Wet work exposure and hand eczema among healthcare workers: a cross-sectional study. Br J Dermatol. 2018;178:452–61.
188. Pedersen LK, Held E, Johansen JD, Agner T. Less skin irritation from alcohol-based disinfectant than from detergent used for hand disinfection. Br J Dermatol. 2005;153:1142–6.
189. Slotosch CM, Kampf G, Löffler H. Effects of disinfectants and detergents on skin irritation. Contact Derm. 2007;57:235–41.
190. Lachapelle JM. Efficacy of protective creams and/or gels. Curr Probl Dermatol. 1996;25:182–92.
191. Lodén M. Barrier recovery and influence of irritant stimuli in skin treated with a moisturizing cream. Contact Derm. 1997;36:256–60.
192. Wigger-Alberti W, Elsner P. Preventive measures in contact dermatitis. Clin Dermatol. 1997;15:661–5.
193. Hannuksela M. Moisturizers in the prevention of contact dermatitis. Curr Probl Dermatol. 1996;25:214–20.
194. Zhai H, Maibach HI. Moisturizers in preventing irritant contact dermatitis: an overview. Contact Derm. 1998;38:241–4.
195. Williams C, Wilkinson SM, McShane P, Lewis J, Pennington D, Pierce S, et al. A double-blind, randomized study to assess the effectiveness of different moisturizers in preventing dermatitis induced by hand washing to simulate healthcare use. Br J Dermatol. 2010;162:1088–92.
196. Wilke A, Skudlik C, Sonsmann FK. Individualprävention beruflicher Kontaktekzeme: Schutzhandschuhe und Hautschutzempfehlungen im berufsgenossenschaftlichen Heilverfahren. Hautarzt. 2018;69:449–61.

197. Allmers H, Schmengler J, John SM. Decreasing incidence of occupational contact urticaria caused by natural rubber latex allergy in German health care workers. J Allergy Clin Immunol. 2004;114:347–51.
198. Geier J, Lessmann H, Mahler V, Pohrt U, Uter W, Schnuch A. Occupational contact allergy caused by rubber gloves—Nothing has changed. Contact Derm. 2012;67:149–56.
199. Ramsing DW, Agner T. Effect of glove occlusion on human skin (I). Short-term experimental exposure. Contact Derm. 1996;34:1–5.
200. Ramsing DW, Agner T. Effect of glove occlusion on human skin (II). Long-term experimental exposure. Contact Derm. 1996;34:258–62.
201. Tiedemann D, Clausen ML, John SM, Angelova-Fischer I, Kezic S, Agner T. Effect of glove occlusion on the skin barrier. Contact Derm. 2016;74:2–10.
202. Wigger-Alberti W, Elsner P. Do barrier creams and gloves prevent or provoke contact dermatitis? Am J Contact Dermat. 1998;9:100–6.
203. Diepgen TL, Schmidt A, Bernhard-Klimt C, Dickel H, Kuss O, Bruckner T, et al. Epidemiologie von Berufsdermatosen. In: Szliska C, Brandenburg S, John SM, editors. Berufsdermatosen. Prävention – Exposition – Begutachtung – Rehabilitation – Therapie. München, Deisenhofen: Dustri; 2006. pp. 45–67.
204. Krohn S, Drechsel-Schlund C, Römer W, Wehrmann W, Skudlik C. Rechtsänderungen bei Berufskrankheiten – Auswirkungen auf die dermatologische Praxis. Dermatol Beruf Umwelt. 2020;68:145–8.
205. Dickel H, Kuss O, Schmidt A, Kretz J, Diepgen TL. Importance of irritant contact dermatitis in occupational skin disease. Am J Clin Dermatol. 2002;3:283–9.
206. Dickel H, Kuss O, Schmidt A, Diepgen TL. Occupational relevance of positive standard patch-test results in employed persons with an initial report of an occupational skin disease. Int Arch Occup Environ Health. 2002;75:423–34.
207. Brans R, Skudlik C. Prävention des Handekzems. Hautarzt. 2019;70:797–803.