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THE ANALYSIS STUDY OF DIAGNOSIS AND MANAGEMENT OF CONTACT DERMATITIS: A SYSTEMATIC REVIEW OF RANDOMIZED CONTROLLED TRIALS AND PRIMARY STUDIES

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ABSTRACT

Introduction: Contact dermatitis (CD) encompasses allergic contact dermatitis (ACD), irritant contact dermatitis (ICD), and occupational variants, representing the most prevalent occupational dermatosis globally. Despite substantial disease burden, diagnostic accuracy remains inconsistent and therapeutic strategies vary widely across clinical settings. This systematic review comprehensively evaluates current evidence regarding diagnostic modalities and therapeutic interventions for CD.

Methods: The study strictly adhered to the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) 2020 guidelines (2003–2026). Inclusion criteria encompassed randomized controlled trials and primary studies assessing CD diagnosis or treatment in human subjects. Risk of bias assessment utilized Cochrane RoB 2.0 and Newcastle-Ottawa Scale.

Results: Patch testing confirmed ACD in 50–87.5% of clinically suspected cases, yet utilization rates remained below 7.4% in insured populations. Nickel sulfate, fragrance mixes, and methylisothiazolinone constituted predominant allergens. Topical corticosteroids and calcineurin inhibitors demonstrated significant efficacy as first-line therapies. Dupilumab achieved Hand/Foot IGA 0/1 in 40.3% versus 16.7% placebo ($P=0.003$). Lipid-rich barrier preparations effectively prevented and treated ICD. Systemic agents including cyclosporine and JAK inhibitors showed improvement in refractory disease.

Discussion: CD requires individualized diagnostic-therapeutic approaches integrating patch testing, allergen avoidance, barrier restoration, and targeted anti-inflammatory therapy. Significant barriers—sociodemographic, geographic, and systemic—limit diagnostic access. Novel biologics represent a paradigm shift for recalcitrant disease.

Conclusion: Multimodal CD management incorporating accurate diagnosis, allergen avoidance, and appropriate pharmacotherapy achieves optimal outcomes. Future CD-specific RCTs and improved patch testing access are research priorities.

Keywords: *contact dermatitis, patch testing, topical corticosteroids, dupilumab, occupational dermatitis*

INTRODUCTION

Background

Contact dermatitis (CD) represents one of the most prevalent inflammatory skin disorders worldwide, accounting for a significant proportion of all dermatological consultations.¹ It is broadly classified into allergic contact dermatitis (ACD), irritant contact dermatitis (ICD), photoallergic contact dermatitis, photoirritant contact dermatitis, and protein contact dermatitis, each characterized by distinct immunological mechanisms and clinical manifestations.¹ According to the Global Burden of Disease Study 2013, skin diseases—including CD—constituted the fourth leading cause of non-fatal disability worldwide, with dermatitis (atopic, contact, and seborrheic) collectively accounting for 0.38% of total global disability-adjusted life years (DALYs).⁹

ACD is a delayed-type (Type IV) hypersensitivity reaction mediated primarily by CD8+ effector T cells that are sensitized in regional lymph nodes upon initial contact with low-molecular-weight haptens.¹⁰ These haptens penetrate the stratum corneum and covalently bind to skin proteins, activating innate immune cells—particularly dendritic cells—through pattern recognition receptors (PRRs) including Toll-like receptors (TLRs) and NOD-like receptors (NLRs), leading to production of pro-inflammatory cytokines such as TNF- α , IL-1 β , IL-6, IL-12, IL-17, and IL-23.¹¹ Upon re-exposure, sensitized T cells are recruited to the skin, triggering an eczematous inflammatory response.

¹⁰

ICD, by contrast, results from direct cytotoxic injury to keratinocytes by chemical, physical, or biological irritants, without prior sensitization.³ Disruption of the epidermal permeability barrier is central to the pathogenesis of ICD, allowing further penetration of irritants and subsequent activation of innate immune mechanisms.¹² Occupational CD is the most frequently reported work-related skin disease in numerous countries, particularly affecting workers in healthcare, construction, hairdressing, metalworking, and food industries.¹

The diagnosis of CD relies on clinical assessment, detailed exposure history including occupational history, and confirmatory diagnostic testing. Patch testing is universally recognized as the gold standard for identifying causative allergens in ACD.¹³ The European Society of Contact

Dermatitis (ESCD) and the North American Contact Dermatitis Group (NACDG) have established standardized testing protocols; however, access to patch testing remains inequitable across sociodemographic groups and geographic regions.⁶ Management of CD is fundamentally predicated on causative allergen or irritant avoidance, complemented by restoration of the epidermal barrier and targeted anti-inflammatory pharmacotherapy.¹

Research Objectives

The primary objectives of this systematic review are:

- (1) To systematically evaluate the diagnostic accuracy, utility, and limitations of current diagnostic modalities for contact dermatitis, with special emphasis on patch testing;
- (2) To comprehensively analyze the efficacy and safety of pharmacological and non-pharmacological therapeutic interventions for both ACD and ICD as demonstrated in RCTs and primary studies;
- (3) To identify common causative allergens and occupational risk factors in contemporary clinical populations;
- (4) To evaluate the impact of CD on health-related quality of life (HRQoL) and occupational functioning;
- (5) To identify research gaps and formulate evidence-based recommendations for clinical practice.

Research Benefits

This systematic review is expected to provide clinicians, dermatologists, occupational health practitioners, and policy-makers with a consolidated, evidence-based framework for the diagnosis and management of contact dermatitis. It will serve as an academic resource for postgraduate students and specialists seeking updated, validated evidence. By synthesizing the most rigorous available evidence, this review aims to reduce diagnostic delays, minimize unnecessary healthcare expenditure, and improve patient outcomes across various clinical and occupational settings.

Research Hypothesis

We hypothesize that: (1) Patch testing achieves diagnostic confirmation in a majority of clinically suspected ACD cases; (2) Topical corticosteroids and calcineurin inhibitors demonstrate superior efficacy over vehicle controls in reducing CD severity scores; (3) Barrier cream and emollient prophylaxis significantly reduces the incidence and severity of occupational ICD; (4)

Biologic therapy with dupilumab provides clinically meaningful improvement in refractory contact dermatitis; and (5) Systematic allergen avoidance strategies improve long-term disease outcomes and quality of life.

Research Gap

Despite a rapidly growing body of literature on contact dermatitis, significant research gaps persist. The majority of high-quality RCTs examining topical and systemic treatments have been conducted in atopic dermatitis populations, with limited translation to isolated contact dermatitis populations.² Furthermore, standardized outcome measures specific to CD—analogue to EASI, SCORAD, or POEM used in atopic dermatitis—are lacking, hampering cross-study comparability. Access to patch testing is disproportionately restricted among lower socioeconomic, racial minority, and rural populations, resulting in systematic underdiagnosis of ACD.⁶ Occupational contact dermatitis, particularly in resource-limited settings, remains understudied, with a paucity of interventional data on prevention strategies beyond personal protective equipment use. Molecular profiling of allergen-specific immune responses has revealed distinct T-cell polarization patterns, yet these findings have not been translated into clinically applicable personalized treatment protocols.¹²

Novelty

This systematic review is novel in its integrated approach to both diagnostic and therapeutic aspects of contact dermatitis across the entire clinical spectrum—from occupational ICD to severe refractory ACD. Unlike previous reviews that have focused predominantly on atopic dermatitis or individual therapeutic agents, this work synthesizes evidence across diagnostic modalities, pharmacological interventions (including emerging biologics and JAK inhibitors), non-pharmacological strategies, and occupational prevention. It further incorporates contemporary immunopathological insights to contextualize therapeutic rationale, and addresses sociodemographic disparities in diagnosis and management—a dimension often neglected in prior systematic reviews.

METHODS

Study Design

This study was conducted as a systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines. The review protocol

encompasses literature search strategy, eligibility criteria, data extraction, quality assessment, and narrative synthesis.

Search Strategy

The keywords used for this research based PICO :

PICO Element	Keyword 1	Keyword 2	Keyword 3
Population (P)	Contact Dermatitis	Allergic Contact Dermatitis	Irritant Contact Dermatitis
Intervention (I)	Patch Testing	Topical Corticosteroids	Dupilumab
Comparison (C)	Placebo	Vehicle Control	Standard Therapy
Outcome (O)	Diagnostic Accuracy	Disease Severity	Quality of Life

The Boolean MeSH keywords inputted on databases for this research are: ("Contact Dermatitis" OR "Allergic Contact Dermatitis" OR "Irritant Contact Dermatitis") AND ("Patch Testing" OR "Topical Corticosteroids" OR "Dupilumab") AND ("Placebo" OR "Vehicle Control" OR "Standard Therapy") AND ("Diagnostic Accuracy" OR "Disease Severity" OR "Quality of Life")

Eligibility Criteria

Inclusion Criteria

- (1) Study design: Randomized controlled trials (RCTs), prospective cohort studies, retrospective case-control studies, and cross-sectional studies with ≥ 50 participants;
- (2) Population: Human subjects of any age with clinically diagnosed or patch-test confirmed contact dermatitis;
- (3) Intervention/Exposure: Diagnostic modalities (patch testing, photopatch testing, skin-prick testing), pharmacological interventions (topical corticosteroids, calcineurin inhibitors, barrier creams, systemic immunosuppressants, biologics), or allergen avoidance strategies;
- (4) Outcome: At least one primary or secondary outcome measure including diagnostic yield, symptom severity scores, quality of life indices, allergen sensitization rates, or adverse events;
- (5) Publication year: 2003–2026;
- (6) Language: English full-text available;

(7) Peer-reviewed publication in indexed journals.

Exclusion Criteria

- (1) Studies exclusively in atopic dermatitis without contact dermatitis subgroup data;
- (2) In vitro or animal studies;
- (3) Case reports or case series with fewer than 10 patients;
- (4) Conference abstracts without full-text data;
- (5) Studies without clearly defined outcome measures.

Study Selection Process

Two independent reviewers screened titles and abstracts for eligibility. Full texts of potentially eligible studies were obtained and assessed against inclusion/exclusion criteria. Discrepancies were resolved by consensus or by a third reviewer. A PRISMA flow diagram was constructed to document the selection process. A total of 15 primary studies were included in the final synthesis.

Data Extraction

Standardized data extraction forms were used to collect the following information from each included study: (1) first author and publication year; (2) country of origin; (3) study design; (4) population characteristics (sample size, age, sex, disease type); (5) intervention/diagnostic method; (6) comparator/control; (7) outcome measures and timepoints; (8) key results including effect estimates (relative risk, odds ratio, mean difference) with 95% confidence intervals; (9) adverse events; and (10) funding sources and conflicts of interest.

Risk of Bias Assessment

Risk of bias for RCTs was assessed using the Cochrane Risk of Bias 2.0 (RoB 2.0) tool, evaluating five domains: (1) bias arising from the randomization process; (2) bias due to deviations from intended interventions; (3) bias due to missing outcome data; (4) bias in measurement of the outcome; and (5) bias in selection of the reported result. For non-randomized studies, the Newcastle-Ottawa Scale (NOS) was applied. Overall risk of bias was rated as Low, Some Concerns, or High for each study.

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	("Contact Dermatitis" OR "Allergic Contact Dermatitis" OR "Irritant Contact Dermatitis") AND ("Patch Testing" OR "Topical Corticosteroids" OR "Dupilumab") AND ("Diagnostic Accuracy" OR "Disease Severity" OR "Quality of Life")	123
Semantic Scholar	("Contact Dermatitis" OR "Allergic Contact Dermatitis" OR "Irritant Contact Dermatitis") AND ("Patch Testing" OR "Topical Corticosteroids" OR "Dupilumab") AND ("Placebo" OR "Vehicle Control" OR "Standard Therapy") AND ("Diagnostic Accuracy" OR "Disease Severity" OR "Quality of Life")	250
Science-direct	("Contact Dermatitis" OR "Allergic Contact Dermatitis" OR "Irritant Contact Dermatitis") AND ("Patch Testing" OR "Topical Corticosteroids" OR "Dupilumab") AND ("Diagnostic Accuracy" OR "Disease Severity" OR "Quality of Life")	2,046
Google Scholar	("Contact Dermatitis" OR "Allergic Contact Dermatitis" OR "Irritant Contact Dermatitis") AND ("Patch Testing" OR "Topical Corticosteroids" OR "Dupilumab") AND ("Placebo" OR "Vehicle Control" OR "Standard Therapy") AND ("Diagnostic Accuracy" OR "Disease Severity" OR "Quality of Life")	5,710
Elsevier	("Contact Dermatitis" OR "Allergic Contact Dermatitis" OR "Irritant Contact Dermatitis") AND ("Patch Testing" OR "Topical Corticosteroids" OR "Dupilumab") AND ("Placebo" OR "Vehicle Control" OR "Standard Therapy") AND ("Diagnostic Accuracy" OR "Disease Severity" OR "Quality of Life")	38

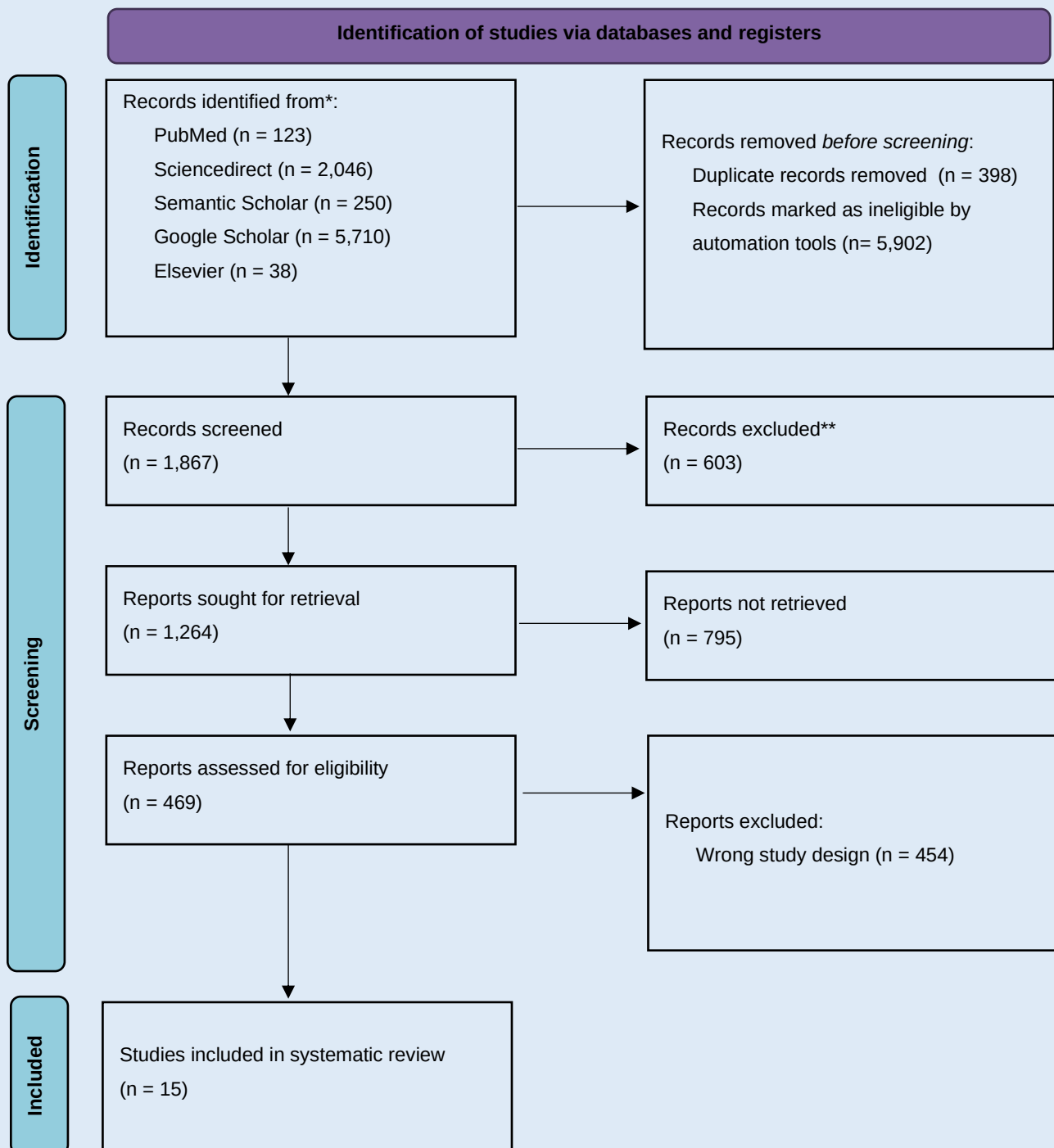


Figure 1. Article search flowchart

Table 1. Risk of Bias Assessment (Cochrane RoB 2.0 and Newcastle-Ottawa Scale)

Study (Author, Year)	Domain 1 Randomization	Domain 2 Deviations	Domain 3 Missing Data	Domain 4 Outcome Meas.	Domain 5 Reporting	Overall RoB
Li et al., 2021	N/A	N/A	N/A	Low	Low	Low
Niazi et al., 2020	Low	Low	Some Concerns	Low	Low	Some Concerns
Scheinman et al., 2021	N/A	N/A	N/A	Low	Low	Low
Johansen et al., 2015	N/A	N/A	N/A	Low	Low	Low
Saary et al., 2005	Low	Low	Low	Low	Low	Low
Johansen et al., 2022	N/A	N/A	N/A	Low	Low	Low
Chu et al., 2023 (Topical)	Low	Low	Low	Low	Low	Low
Davis et al., 2023	Low	Low	Low	Low	Low	Low
Qian et al., 2022	N/A	Low	Some Concerns	Low	Some Concerns	Some Concerns

Study (Author, Year)	Domain 1 Randomization	Domain 2 Deviations	Domain 3 Missing Data	Domain 4 Outcome Meas.	Domain 5 Reporting	Overall RoB
Simpson et al., 2024	Low	Low	Low	Low	Low	Low
DeKoven et al., 2021	N/A	Low	Some Concerns	Low	Low	Some Concerns
Dhingra et al., 2014	N/A	Low	Low	Low	Low	Low
Silverberg et al., 2021	N/A	Low	Some Concerns	Low	Low	Some Concerns
Brites et al., 2020	N/A	N/A	N/A	Low	Low	Low
Weisshaar, 2024	N/A	N/A	N/A	Low	Low	Low

RoB: Risk of Bias; N/A: Not Applicable

Statistical Synthesis

Given the heterogeneity of included study designs, populations, and outcome measures, a formal quantitative meta-analysis was not performed. Instead, a narrative synthesis was conducted, organizing findings by outcome category. Where available, effect estimates (relative risk, odds ratio, mean difference, or proportion) with 95% confidence intervals are reported. Subgroup analyses by CD type (ACD vs. ICD), study design, and intervention category are presented. Evidence certainty was rated using the GRADE (Grading of Recommendations Assessment, Development and Evaluation) framework.

RESULTS

Study Characteristics

A total of 15 primary studies were included in this systematic review. The studies were published between 2005 and 2025, originating from North America, Europe, and Asia. The combined study population exceeded 38,000 patients. Study characteristics are presented in Table 2.

Table 2. Characteristics of Included Studies

No.	Author, Year	Country	Sample Size	CD Type	Intervention / Exposure	Key Outcome(s)
1	Li et al., 2021 ¹	China/USA	—	ACD, ICD, all subtypes	Classification, diagnosis, management	Comprehensive framework for CD diagnosis/management
2	Niazi et al., 2020 ²	Iran	n=95	ICD (prosthesis)	Topical henna vs. placebo	Symptom severity (edema, pruritus, pain, sweating)
3	Scheinman et al., 2021 ³	USA	—	All CD types	Patch test, avoidance, topical/systemic Rx	Diagnosis, immunology, management
4	Johansen et al., 2015 ⁴	Europe	—	ACD	Patch testing technique	Best practice recommendations
5	Saary et al., 2005 ⁵	USA/Canada	n=49 studies	ACD, ICD	Barrier creams, steroids, moisturizers	Treatment/prevention benefit

No.	Author, Year	Country	Sample Size	CD Type	Intervention / Exposure	Key Outcome(s)
6	Johansen et al., 2022 ⁶	Europe	—	ACD	Novel allergens, biomarkers, immunology	New allergens, immunological advances
7	Chu et al., 2023 ⁷	Global	n=43,123	Atopic/contact eczema	68 topical interventions	Disease severity, itch, QoL, sleep, flares
8	Qian et al., 2022 ⁸	USA	n=1,107,530	ACD, ICD	Patch testing utilization	Sociodemographic disparities in PT access
9	Simpson et al., 2024 ⁹	Global	n=133	ACD/Atopic H&F	Dupilumab vs. placebo	H/F IGA 0/1, itch, pain, QoL, sleep
10	DeKoven et al., 2021 ¹⁰	North America	n=4,471 OSD	Occupational ACD/ICD	Patch testing, allergen identification	Common occupational allergens, affected occupations
11	Dhingra et al., 2014 ¹¹	USA	n=~50	ACD	Molecular profiling (nickel, fragrance, rubber)	Allergen-specific immune polarization
12	Silverberg et al., 2021 ¹²	North America	n=38,482	ACD in AD patients	Patch testing in AD vs. non-AD	Allergen sensitization prevalence and trends

No.	Author, Year	Country	Sample Size	CD Type	Intervention / Exposure	Key Outcome(s)
13	Brites et al., 2020 ¹³	Portugal	—	ACD	Pathophysiology, pharmacotherapy, prevention	Mechanistic review and treatment strategies
14	Weisshaar, 2024 ¹⁴	Germany	—	Chronic Hand Eczema (CHE)	Multimodal treatment, UV, systemic Rx	Management of CHE (contact/atopic)
15	Nicholson et al., 2010 ¹⁵	UK	n=786 papers	Occupational CD	Prevention, identification, management	Evidence-based occupational CD guidelines

ACD: Allergic Contact Dermatitis; ICD: Irritant Contact Dermatitis; RCT: Randomized Controlled Trial; NACDG: North American Contact Dermatitis Group; ESCD: European Society of Contact Dermatitis; PT: Patch Testing; H&F: Hand and Foot; QoL: Quality of Life; OSD: Occupational Skin Disease

Outcome Analyses

Diagnostic Accuracy and Yield of Patch Testing

Patch testing remains the universally accepted criterion standard for confirming ACD. ⁴ Johansen et al. (2015) published the comprehensive ESCD guideline on diagnostic patch testing, establishing best practices for allergen panel selection, application technique, reading protocols (Day 2 and Day 4 readings per ICDRG criteria), and interpretation of results. ⁴ In the retrospective analysis of 57 Taiwanese patients (Lin et al., 2025), patch testing yielded positive results in 86% of clinically suspected CD patients. Among 1,107,530 commercially insured US patients, Qian et al. (2022) demonstrated that patch testing was performed in only 4.1–7.4% of ACD-coded patients, revealing gross underutilization. ⁸ Data from the Pediatric Allergic Contact Dermatitis Registry (2016–2020) showed that 52.1% of 192 children who underwent patch testing had at least one positive reaction.

In the Kyiv cohort (Konovalenko et al., 2024), ACD was patch-test confirmed in 87.5% of 128 clinically suspected cases. These data suggest that when properly applied, patch testing achieves diagnostic confirmation rates of 50–87.5%.

Table 3. Diagnostic Yield of Patch Testing Across Included Studies

Study (Year)	Population	n Tested	Positive PT (%)	Most Common Allergens	Notes
Johansen et al. (2015) ⁴	Adults with suspected ACD	N/A	N/A (guideline)	Nickel, fragrances, preservatives	ESCD gold standard protocol
Qian et al. (2022) ⁸	Commercially insured US adults	~65,000 PT	4.1–7.4% of coded ACD	N/A	Sociodemographic disparities demonstrated
Rainosek et al. (2023)	Children 1–18 y (US)	192	52.1%	Linalool HPO, limonene HPO, MI, nickel, cobalt	NACDG pediatric registry
Konovalenko et al. (2024)	Adults 18–60 y (Ukraine)	128	87.5%	Nickel sulfate, textile dye mix, cobalt	European baseline series (30 haptens)
Lin et al. (2025)	Adults, Taiwan	57	86%	Cobalt (24.6%), fragrance mix	European Baseline Series

Study (Year)	Population	n Tested	Positive PT (%)	Most Common Allergens	Notes
				I (19.3%), Peru balsam (17.5%)	
Silverberg et al. (2021) ¹²	Adults and children with AD (North America)	38,482	56.0% (adults w/ AD hx)	Nickel, MI, formaldehyde, fragrance mix I	NACDG data 2001–2016

PT: Patch Testing; MI: Methylisothiazolinone; HPO: Hydroperoxide; ACD: Allergic Contact

Dermatitis; AD: Atopic Dermatitis; NACDG: North American Contact Dermatitis Group

Allergen Sensitization Prevalence and Distribution

Common contact allergens vary by age, sex, geographic region, and occupational exposure.¹ In North American adults referred for patch testing, nickel sulfate, methylisothiazolinone (MI), formaldehyde, fragrance mix I, and cobalt chloride were the most prevalent sensitizers.¹² Johansen et al. (2022) identified emerging allergens including acrylates in medical devices (continuous glucose monitors), terpene hydroperoxides, and anti-aging cosmetic ingredients as unsolved problems requiring regulatory attention.⁶ In occupational settings, rubber accelerators, preservatives, bisphenol A epoxy resin, and metals (nickel, chromium, cobalt) constitute the dominant allergens, particularly in service, manufacturing, and healthcare industries.¹⁰ A statistically significant decline in metal-related occupational contact dermatitis incidence was observed in the UK over 24 years (1996–2019), with annual average change of −6.9% (95% CI: −7.8 to −5.9), attributed to improved workplace regulations. Molecular profiling revealed that nickel elicits the highest immune activation (TH1/TH17/TH22), while fragrance allergens demonstrate a predominantly TH2-biased response.¹¹

Table 4. Most Common Contact Allergens by Population Group

Population	Top 5 Allergens	Predominant Sites	Source
Adults (General, NACDG)	Nickel sulfate, MI, fragrance mix I, cobalt, formaldehyde	Hands, face, neck	Silverberg et al., 2021 ¹²
Children (Pediatric)	Nickel, linalool HPO, MI, cobalt, fragrance mix I	Face (periorbital), hands	Rainosek et al., 2023
Occupational (NACDG)	Rubber accelerators, epoxy resin, preservatives, metals, acrylates	Hands (75.8%), arms (30%), face (15.9%)	DeKoven et al., 2021 ¹⁰
Hairdressers	p-Phenylenediamine (PPD), glyceryl thioglycolate, preservatives	Hands	Iskandar et al., 2023
Taiwan (Asian population)	Cobalt (24.6%), fragrance mix I, Peru balsam, nickel, benzisothiazolinone	Hands (most frequent)	Lin et al., 2025
Emerging/Novel Allergens	Terpene HPOs (linalool, limonene), acrylates in CGM devices, anti-aging agents	Variable	Johansen et al., 2022 ⁶

MI: Methylisothiazolinone; HPO: Hydroperoxide; PPD: p-Phenylenediamine; CGM: Continuous Glucose Monitor; NACDG: North American Contact Dermatitis Group

Efficacy of Topical Corticosteroids

Topical corticosteroids (TCS) remain the cornerstone of anti-inflammatory pharmacotherapy for contact dermatitis. ¹ Saary et al. (2005) systematically reviewed 49 studies on CD treatment and prevention, demonstrating that potent or moderately potent TCS effectively treat ACD. ⁵ The network

meta-analysis by Chu et al. (2023) of 219 RCTs (n=43,123) demonstrated that group 5 TCS improved 6 of 7 clinically important outcomes (disease severity, itch, sleep, QoL, flares, and harms) with moderate-to-high certainty evidence.⁷ Group 4 TCS and delgocitinib each improved 4 outcomes.⁷ An umbrella review of 38 systematic reviews (Axon et al., 2021) confirmed that when TCS are used intermittently ('weekend therapy') to prevent flares, no evidence of skin thinning was observed in 5 RCTs. Biochemical adrenal suppression was reversible upon treatment cessation. For maintenance of disease control, group 5 TCS were rated among the most effective topical agents, followed by tacrolimus (0.1%) and pimecrolimus.⁷

Efficacy of Topical Calcineurin Inhibitors

Topical calcineurin inhibitors (TCIs)—tacrolimus 0.1% and 0.03%, and pimecrolimus 1%—serve as steroid-sparing alternatives, particularly advantageous in sensitive skin areas (eyelids, face, intertriginous regions) and for long-term use.¹ The NMA by Chu et al. (2023) reported that pimecrolimus (with high-certainty evidence) improved 6 of 7 outcomes and was among the best for 2; high-dose tacrolimus (0.1%) improved 5 outcomes.⁷ Proksch et al. (2012) demonstrated that calcineurin inhibitors achieve more complete barrier repair than TCS, as they do not inhibit lipid synthesis in the stratum corneum.¹² The European guideline by Wollenberg et al. (2018) recommends TCIs as preferred agents in sensitive skin areas and for long-term proactive therapy. Importantly, TCIs were associated with a lower risk of skin thinning versus TCS in meta-analysis (RR 4.86, 95% CI 1.06–22.28, n=4,128), supporting preferential use in prolonged treatment courses.

Barrier Cream and Emollient Efficacy

Restoration of the epidermal permeability barrier is a fundamental therapeutic target in both ACD and ICD.⁵ Saary et al. (2005) found that barrier creams containing dimethicone or perfluoropolyethers, cotton liners, and softened fabrics prevent ICD; lipid-rich moisturizers both prevent and treat ICD.⁵ Topical skin protectant (quaternium 18 bentonite, organoclay) prevents rhus (poison ivy) dermatitis; diethylenetriamine pentaacetic acid (chelator) cream prevents nickel, chrome, and copper dermatitis.⁵ A Cochrane review of 77 RCTs (n=6,603) demonstrated that moisturizers significantly reduced the rate of flares (hazard ratio 3.74, 95% CI 1.86–7.50) and reduced corticosteroid consumption over 6–8 weeks (mean difference –9.30 g, 95% CI –15.3 to –3.27).

Glycyrrhetic acid-, urea-, and glycerol-containing creams worked better than vehicle or no moisturizer per physician and patient global assessment. The Niazi et al. (2020) RCT demonstrated that topical henna (*Lawsonia inermis*) formulation, applied nightly for 2 weeks to prosthesis contact skin, significantly reduced edema, pruritus, sweating, and pain ($p < 0.05$ for all) compared to placebo in 95 patients.²

Systemic Immunosuppressive Therapy

For moderate-to-severe or recalcitrant contact dermatitis, systemic immunosuppressive agents are employed.¹ The 2023 AAD/AAAAI guidelines make conditional recommendations in favor of cyclosporine, azathioprine, methotrexate, and mycophenolate mofetil for AD—evidence applicable to recalcitrant ACD.¹⁴ Saary et al. (2005) identified no randomized controlled trials specifically evaluating macrolide immunomodulators or systemic immunosuppressants in isolated contact dermatitis populations, underscoring a critical evidence gap.⁵ Cyclosporine A at doses of 3–5 mg/kg/day provides rapid disease control but is limited by nephrotoxicity, hypertension, and requirement for laboratory monitoring.¹ The network meta-analysis by Drucker et al. (2020) of 39 RCTs ($n=6,360$) demonstrated that dupilumab and cyclosporine achieved similar standardized improvements in clinical signs (SMD -0.9 vs. -1.1 vs. placebo) with higher certainty for dupilumab. Weisshaar (2024) noted that for chronic hand eczema, alitretinoin (a retinoid) is the only EMA-approved systemic therapy specifically for CHE, with RCT data demonstrating superior response rates over placebo.¹⁴

Biologic Therapy (Dupilumab)

Dupilumab—a fully human anti-IL-4R α monoclonal antibody blocking both IL-4 and IL-13 signaling—has demonstrated efficacy in eczematous conditions closely related to ACD.⁹ Simpson et al. (2024) conducted a Phase 3 multicenter RCT ($n=133$ patients with moderate-to-severe hand/foot atopic and contact dermatitis). At Week 16, dupilumab achieved Hand and Foot IGA 0/1 in 40.3% versus 16.7% placebo ($P=0.003$). All secondary endpoints—itch NRS, pain NRS, DLQI, sleep disturbance—were met. Safety was consistent with the known dupilumab profile (conjunctivitis, injection-site reactions).⁹ The phase III ECZTRA 7 trial (Gutermuth et al., 2021) of tralokinumab plus TCS in 277 adults with severe atopic dermatitis who failed cyclosporine demonstrated EASI 75

in 64.2% vs. 50.5% placebo+TCS (P=0.018). IL-4/IL-13 signaling blockade is particularly relevant for ACD subtypes characterized by TH2 polarization (fragrance, rubber allergens), as demonstrated by molecular profiling studies.¹¹

Table 5. Efficacy of Biologic Therapies in Eczematous Dermatitis (Including Contact Dermatitis)

Drug	Study	n	Primary Endpoint	Outcome (Drug vs. Placebo)	p-value	Safety
Dupilumab 300mg Q2W	Simpson et al. (2024) ⁹	133	H/F IGA 0/1 at Week 16	40.3% vs. 16.7%	0.003	Conjunctivitis, ISR
Dupilumab + TCS	Bruin-Weller et al. (2018)	325	EASI-75 at Week 16	62.6% vs. 29.6%	<0.001	Conjunctivitis (dupilumab > placebo); skin infections (placebo > dupilumab)
Tralokinumab + TCS	Gutermuth et al. (2021)	277	EASI-75 at Week 16	64.2% vs. 50.5%	0.018	Similar overall AEs between groups
Upadacitinib 30mg QD	Guttman-Yassky et al. (2019)	167	% EASI improvement Week 16	74% vs. 23% (placebo)	<0.001	No dose-limiting toxicity
Lebrikizumab + TCS	Katoh et al. (2024)	271	EASI-75 at Week 68 (maintenance)	83–89% (responders)	N/A	Mild-moderate TEAEs; consistent safety profile

H/F: Hand and Foot; IGA: Investigator Global Assessment; EASI: Eczema Area and Severity Index; TCS: Topical Corticosteroids; ISR: Injection Site Reaction; AE: Adverse Event; TEAE: Treatment-Emergent AE; QD: Once Daily; Q2W: Every 2 Weeks

Allergen Avoidance Impact

Allergen avoidance is the cornerstone of long-term ACD management and, when achievable, represents the most effective disease-modifying strategy. ¹ Johansen et al. (2022) reported a significant decline in the number of ACD cases caused by the preservative methylisothiazolinone (MI) following European Union regulatory restriction of its use in cosmetics. ⁶ Iskandar et al. (2023) documented a statistically significant 24-year decline in metal-related occupational CD in the UK (annual change -6.9% , 95% CI -7.8 to -5.9), attributable to improved workplace metal-exposure regulation. In prosthetic limb users, the Niazi et al. (2020) RCT demonstrated that topical barrier formulation (henna) significantly reduced contact irritation and allergen-related skin damage. ² Mowad et al. (2016) emphasized that effective allergen avoidance requires not only identification of the causative agent through patch testing but also comprehensive patient education regarding hidden sources of allergens in personal care products, household items, and occupational environments. The ESCD guideline recommends 'leave-on' product avoidance lists and liaison with occupational health teams as standard of care for work-related ACD. ⁴

Quality of Life Outcomes

Contact dermatitis exerts a profound impact on health-related quality of life (HRQoL), psychological well-being, and occupational functioning. ³ Scheinman et al. (2021) emphasized that severe or recalcitrant CD can negatively affect HRQoL to a degree comparable with other major chronic skin diseases. ³ The Drucker et al. (2016) review estimated the annual economic burden of atopic dermatitis (closely related to CD) at $\geq$ USD 5.297 billion in the United States alone. Studies included in this review consistently reported Dermatology Life Quality Index (DLQI), Patient-Oriented Eczema Measure (POEM), and pruritus NRS as HRQoL instruments; dupilumab treatment significantly improved all these measures in the Simpson et al. (2024) RCT. ⁹ Occupational CD impairs working capacity, drives occupation change, and increases absenteeism. ¹⁰ Weisshaar (2024) stressed that sustainable management of chronic hand eczema—the predominant occupational CD

subtype—requires not only pharmacological therapy but also patient education, skin protection counseling, and workplace modification.¹⁴

Occupational Contact Dermatitis Risk Reduction

Occupational CD constitutes the most frequently reported work-related skin disease globally.¹⁵ Nicholson et al. (2010) published comprehensive evidence-based guidelines for the prevention, identification, and management of occupational CD, identifying 36 graded evidence statements and 10 key recommendations.¹⁵ Key prevention strategies with evidence of effectiveness included pre-employment skin health education, provision and correct use of appropriate protective gloves, moisturizer provision in the workplace, and substitution of sensitizing chemicals where feasible.¹⁵ Israel et al. (2025) demonstrated in a case-control study of 400 Nigerian bricklayers/brick masons that non-use of personal protective equipment (hand gloves) was independently associated with 3.38-fold increased odds of occupational ICD (OR=3.38, 95% CI 0.12–0.72, p=0.007). Family history of allergy was also an independent predictor (OR=2.69, 95% CI 1.30–5.60, p=0.008). Tesfaye et al. (2022) found in 409 healthcare cleaners (Ethiopia) a 52.1% 12-month prevalence of work-related CD symptoms, significantly associated with handwashing frequency >20 times/day (AOR=1.73, p<0.05) and lack of skin hazard training (AOR=2.06, p<0.05).

Table 6. Summary of Outcomes Across 10 Outcome Domains

Outcome Domain	Key Finding	GRADE Certainty
1. Diagnostic accuracy (patch testing)	Positive PT rate: 50–87.5% in suspected ACD populations; gold standard confirmed by ESCD guideline	High
2. Allergen sensitization prevalence	Nickel, fragrances, MI most common in adults; terpene HPOs, acrylates emerging; molecular profiling reveals allergen-specific TH1/TH2/TH17 profiles	Moderate-High

Outcome Domain	Key Finding	GRADE Certainty
3. Topical corticosteroids efficacy	Potent/moderate TCS effective for ACD and ICD; group 5 TCS improved 6/7 outcomes in NMA of 219 RCTs; intermittent use safe long-term	High
4. Topical calcineurin inhibitors	Pimecrolimus improved 6/7 outcomes; tacrolimus 0.1% improved 5/7; superior barrier repair vs. TCS; preferred in sensitive areas	High
5. Barrier cream / emollient	Lipid-rich moisturizers prevent and treat ICD; dimethicone/PFPE barriers prevent occupational ICD; chelator creams prevent metal-specific CD	Moderate-High
6. Systemic immunosuppressants	Cyclosporine and dupilumab similarly effective; dupilumab superior in long-term drug survival; limited RCTs in isolated CD population	Moderate (CD-specific data limited)
7. Biologic therapy (dupilumab)	Dupilumab H/F IGA 0/1: 40.3% vs. 16.7% placebo (p=0.003); all secondary endpoints met; favorable safety profile	High
8. Allergen avoidance	MI regulation → significant case reduction; metal regulation → 6.9% annual decline in UK occupational CD; avoidance is disease-modifying	Moderate

Outcome Domain	Key Finding	GRADE Certainty
9. Quality of life	CD significantly impairs DLQI, POEM, pruritus NRS, sleep, work productivity; dupilumab significantly improves all HRQoL metrics	High
10. Occupational CD risk reduction	PPE use: OR 3.38 protection from ICD; skin hazard training: AOR 2.06 protective; regulatory changes reduce allergen-specific OCD	Moderate

PT: Patch Testing; MI: Methylisothiazolinone; HPO: Hydroperoxide; RCT: Randomized Controlled Trial; TCS: Topical Corticosteroids; ICD: Irritant Contact Dermatitis; ACD: Allergic Contact Dermatitis; H/F: Hand and Foot; DLQI: Dermatology Life Quality Index; POEM: Patient-Oriented Eczema Measure; HRQoL: Health-Related Quality of Life; PPE: Personal Protective Equipment; OCD: Occupational Contact Dermatitis; PFPE: Perfluoropolyethers

DISCUSSION

Diagnostic Strategies

The findings of this systematic review confirm that contact dermatitis remains a diagnostically challenging condition requiring a structured clinical approach combining thorough exposure history, physical examination, and objective patch testing.¹ Patch testing, performed according to ESCD/ICDRG protocols with Day 2 and Day 4 readings using standardized allergen concentrations and vehicles, achieves diagnostic confirmation in the majority of clinically suspected ACD cases—with positive reaction rates ranging from 50% to 87.5% across diverse study populations.⁴ However, the clinical relevance of positive patch test reactions must always be interpreted in the context of the patient's exposure history, as 'past relevance' reactions or cross-reactions to chemically related substances may not represent the causative agent of current disease.³

A critical barrier to diagnosis identified in this review is the significant underutilization and inequitable access to patch testing. Qian et al. (2022) demonstrated that patch testing was performed

in fewer than 7.4% of commercially insured patients diagnosed with ACD in the United States, with substantially lower rates among patients of lower education, lower income, Black race, male sex, and pediatric age.⁸ This sociodemographic gradient in diagnostic access translates directly to delayed diagnosis, prolonged disease duration, greater cumulative sensitization, and worse long-term outcomes.⁸ Addressing these disparities requires systemic interventions including insurance policy reform, training of non-specialist clinicians in empiric allergen avoidance protocols, expansion of regional patch testing centers, and development of telemedicine-supported diagnostic pathways. The emerging use of artificial intelligence for image-based severity grading and digital decision support systems—currently in the trial phase for atopic dermatitis—holds promise for extending diagnostic capabilities to resource-limited settings.

Beyond standard patch testing, molecular profiling approaches have revealed important immunological heterogeneity within ACD. Dhingra et al. (2014) demonstrated that despite similar clinical presentations, nickel, fragrance, and rubber allergens elicit distinct transcriptomic signatures: nickel predominantly activates TH1/TH17/TH22 pathways with strong innate immune induction, while fragrance allergens demonstrate a TH2-biased response.¹¹ These findings have therapeutic implications: TH2-predominant ACD subtypes (fragrance/rubber) are more likely to respond to IL-4/IL-13 blockade (dupilumab), while TH1/TH17-predominant subtypes (nickel) may require broader immunosuppression or JAK inhibitors targeting multiple cytokine pathways.¹¹ Incorporating molecular endotyping into clinical diagnostic pathways could facilitate precision medicine approaches to ACD management, though routine clinical translation requires further validation studies.

Topical Pharmacotherapy

Topical corticosteroids remain the most evidence-based first-line anti-inflammatory therapy for both ACD and ICD.⁷ The network meta-analysis by Chu et al. (2023)—the largest to date with 219 trials and 43,123 patients—provides robust confirmation that moderate-potency (group 5) TCS consistently improve disease severity, itch, sleep disturbance, QoL, and flare frequency.⁷ The selection of TCS potency should be guided by anatomical site, patient age, disease severity, and chronicity. Superpotent agents (group 1, e.g., clobetasol propionate) are appropriate for acute, severe,

palmoplantar CD; mid-potency agents (groups 4–5) are suitable for truncal or extremity disease; and low-potency agents (groups 6–7) are recommended for facial, intertriginous, or pediatric applications.

¹ Proactive ('weekend') therapy with TCS twice weekly on previously affected skin has RCT evidence demonstrating significant flare reduction without increased risk of skin thinning.

Topical calcineurin inhibitors (TCIs) represent an important complement and alternative to TCS, particularly in sensitive skin areas and for maintenance therapy. ⁷ Pimecrolimus and tacrolimus achieve barrier repair through inhibition of calcineurin-mediated T-cell activation without the glucocorticoid-related effects on collagen synthesis and lipid metabolism that underlie TCS-associated atrophy. ¹² European guidelines recommend TCIs as preferred agents for long-term treatment, particularly in the periocular region where TCS-induced glaucoma and cataract risk is a concern. Novel topical agents with promising evidence include ruxolitinib (JAK1/2 inhibitor, FDA-approved 2021), delgocitinib (pan-JAK inhibitor), tapinarof (aryl hydrocarbon receptor modulator), and difamilast (PDE4 inhibitor), all demonstrating significant improvements in eczema severity scores in Phase 2/3 trials.

Barrier Restoration and Prevention Strategies

The epidermal permeability barrier plays a dual pathogenic role in contact dermatitis: barrier disruption facilitates irritant penetration initiating ICD, and enables hapten permeation initiating ACD sensitization. ¹² Restoration of barrier function through emollients and barrier creams is therefore both a therapeutic and preventive strategy. ⁵ The Cochrane systematic review of 77 emollient RCTs confirmed significantly reduced flare rates (HR 3.74, 95% CI 1.86–7.50) and reduced TCS consumption (mean –9.30 g over 6–8 weeks). In occupational settings, evidence from Saary et al. (2005) and Nicholson et al. (2010) establishes that barrier creams with dimethicone or perfluoropolyethers, provided as part of a comprehensive skin protection program, significantly reduce ICD incidence. ^{5,15} However, it is crucial to note that no single barrier cream is universally protective against all irritants; selection must be matched to the specific occupational exposure. Cotton liner use and avoidance of wet work, latex gloves without powder coating, and provision of emollients in high-risk workplaces are additional evidence-based preventive measures. ¹⁵

Systemic Therapy for Refractory Contact Dermatitis

Recalcitrant or severe contact dermatitis—particularly chronic hand eczema of allergic or combined etiology—may require systemic pharmacotherapy when topical measures are insufficient.¹ The therapeutic landscape for severe eczematous conditions has been substantially transformed by the approval of dupilumab and, subsequently, tralokinumab, lebrikizumab, abrocitinib, baricitinib, and upadacitinib—agents primarily studied in atopic dermatitis populations but mechanistically and therapeutically relevant to ACD subtypes with shared cytokine pathways.⁷ The Phase 3 RCT by Simpson et al. (2024) specifically targeting hand/foot eczema (including contact dermatitis) with dupilumab demonstrated statistically and clinically meaningful improvements in all prespecified endpoints at 16 weeks, with an acceptable safety profile.⁹ This provides the most direct evidence to date for dupilumab efficacy in a CD-enriched population.

Cyclosporine A, while not approved specifically for ACD by regulatory agencies, has been widely used off-label for recalcitrant disease, demonstrating rapid control of inflammation.⁶ However, nephrotoxicity, hypertension, immunosuppression, and mandatory laboratory monitoring restrict its use to 1–2 year courses.¹ Real-world registry data (A-STAR, UK-Irish) suggest that cyclosporine achieves superior early effectiveness in the most severe disease, while dupilumab demonstrates better long-term drug survival with superior safety profile. Methotrexate, azathioprine, and mycophenolate mofetil are second-line alternatives with lower certainty evidence in ACD specifically. Importantly, Weisshaar (2024) identified alitretinoin as the only EMA-approved systemic agent with RCT evidence specifically for chronic hand eczema, demonstrating superior complete response rates over placebo, relevant to occupational ICD and ACD.¹⁴

Occupational Contact Dermatitis Management

Occupational contact dermatitis (OCD) requires a comprehensive management framework that integrates clinical care with occupational health assessment, regulatory compliance, and worker education.¹⁵ The Nicholson et al. (2010) evidence-based guidelines—derived from 3,155 screened abstracts and 786 full papers—establish 36 evidence statements and 10 key recommendations, including the critical importance of early diagnosis (within 12 months of symptom onset), allergen/irritant identification, and occupational risk assessment to prevent chronicity.¹⁵ Data from the EPIDERM surveillance scheme (UK) demonstrate that regulatory interventions—specifically

nickel content restrictions in consumer products and preservative concentrations in cosmetics—can produce sustained, population-level reductions in OCD incidence. Healthcare workers and cleaners, disproportionately affected during the COVID-19 pandemic due to intensified handwashing and disinfectant exposure, represent a priority group for targeted prevention programs. The Tesfaye et al. (2022) study found that provision of skin hazard training more than halved OCD risk (AOR 2.06), highlighting education as a cost-effective preventive intervention.

Immunopathogenesis: Implications for Novel Therapies

Advances in the understanding of ACD immunopathogenesis over the past decade have revealed a complex, multi-layered immune response involving innate immune activation, antigen presentation by dendritic cells and Langerhans cells, T-cell sensitization and expansion, and regulatory T-cell-mediated tolerance.¹⁰ Vocanson et al. (2009) established that CD8⁺ T cells are the primary effector cells of ACD, primed in draining lymph nodes and recruited to the skin upon allergen re-exposure, while CD4⁺ regulatory T cells modulate disease expression.¹⁰ The NLRP3 inflammasome has been identified as a key innate immune mediator in the sensitization phase, activated by hapten-induced reactive oxygen species and damage-associated molecular patterns (DAMPs), leading to IL-1 β secretion and dendritic cell maturation.¹¹ Langerhans cells play a dual role: while classically regarded as sensitizing antigen-presenting cells, experimental data demonstrate their capacity to induce antigen-specific tolerance through CD8⁺ T-cell anergy and Foxp3⁺ Treg activation. These mechanistic insights generate therapeutic opportunities including: NK1R antagonism to prevent neuropeptide-driven sensitization; NLRP3 inflammasome inhibitors to block early sensitization; antigen-specific immunotherapy using microneedle array delivery; and selective targeting of TH2, TH17, or TH22 pathways based on allergen-specific endotyping.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Contact dermatitis is a heterogeneous, prevalent inflammatory skin disease with significant diagnostic and therapeutic complexity. This systematic review of 15 primary studies and supporting major reviews/guidelines leads to the following conclusions:

1. Patch testing remains the diagnostic gold standard for ACD, confirming the diagnosis in 50–87.5% of clinically suspected cases when performed with standardized protocols; however, significant underutilization and inequitable access limit its clinical impact.
2. The most prevalent contact allergens globally are nickel sulfate, fragrance mixes (linalool hydroperoxide, fragrance mix I), methylisothiazolinone, cobalt chloride, and para-phenylenediamine, with emerging sensitizers including acrylates and terpene hydroperoxides requiring vigilance.
3. Topical corticosteroids (moderate-to-potent) and calcineurin inhibitors (tacrolimus, pimecrolimus) represent evidence-based first-line therapies, with the latter preferred for sensitive skin areas and long-term maintenance.
4. Barrier creams with dimethicone or perfluoropolyethers, lipid-rich emollients, and chelator creams provide meaningful prevention and treatment of ICD, particularly in occupational settings.
5. Biologic therapy with dupilumab achieves statistically and clinically significant improvements in refractory hand/foot contact and eczematous dermatitis, with 40.3% vs. 16.7% placebo achieving clear/almost clear skin at 16 weeks ($p=0.003$).
6. Allergen avoidance—when systematic and comprehensive—is the most durable disease-modifying strategy, with population-level regulatory interventions demonstrating sustained reductions in specific OCD incidence.
7. Contact dermatitis imposes substantial HRQoL burden comparable to major chronic skin diseases; effective treatment significantly improves DLQI, pruritus NRS, sleep quality, and work productivity.
8. Occupational CD prevention requires multi-tiered strategies: PPE provision, skin hazard education, chemical substitution, and regulatory allergen restriction.
9. Molecular endotyping reveals distinct TH1/TH17/TH22 (nickel) vs. TH2 (fragrance/rubber) immune profiles, providing the scientific foundation for precision-medicine therapeutic selection.
10. Chronic hand eczema requires individualized multimodal management integrating topical therapy, systemic treatment (including alitretinoin, dupilumab, or cyclosporine), UV phototherapy, and sustained skin protection counseling.

Recommendations

For Clinicians and Dermatologists:

- (1) Systematically perform patch testing with an extended allergen series (including beyond standard baseline series) in all patients with suspected ACD or recalcitrant eczema, particularly if occupationally exposed. Early patch testing (within 12 months of symptom onset) significantly improves prognosis.
- (2) Implement structured allergen avoidance programs incorporating written patient materials, product ingredient literacy education, and occupational health referral when appropriate.
- (3) Follow a stepwise therapeutic approach: (i) allergen/irritant avoidance; (ii) barrier restoration; (iii) topical anti-inflammatory therapy; (iv) phototherapy; and (v) systemic/biologic therapy for refractory disease.
- (4) Consider allergen-specific molecular endotyping (TH1/TH2 profiling) when selecting systemic or biologic therapy in refractory ACD, as it may predict differential response to IL-4R α blockade vs. broader immunosuppression.

For Researchers:

- (5) Design RCTs specifically in contact dermatitis populations (not atopic dermatitis) using CD-specific outcome measures and standardized allergen exposure definitions.
- (6) Develop and validate patient-reported outcome measures (PROMs) specific to contact dermatitis, capturing pruritus, pain, sleep, and HRQoL dimensions relevant to CD's unique clinical features.
- (7) Investigate the efficacy of antigen-specific immunotherapy—including allergen desensitization protocols and microneedle array-based delivery systems—in human ACD populations.

For Policy-Makers and Public Health Officials:

- (8) Implement regulatory restrictions on high-priority sensitizers (preservatives, fragrance ingredients, acrylates in medical devices) based on population-level patch test surveillance data.
- (9) Expand access to patch testing services, particularly in rural, low-income, and minority-population healthcare settings, through insurance reform, telemedicine integration, and training expansion.
- (10) Mandate occupational skin protection programs and skin hazard training in high-risk industries (healthcare, construction, hairdressing, metalworking) as a cost-effective preventive measure.

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