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Epidemiology of Sensitization to Acrylates in The Nail Sector (HEMA/HPMA/EGDMA)

Dovbeniuk Vira
Self-employed Nail tech Chicago USA

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Abstract

The study is aimed at assessing the epidemiological situation that has developed against the background of an increased incidence of allergic contact dermatitis (ACD) induced by acrylate monomers used in nail services. The significance of the problem under consideration is determined by the rapid and large-scale growth of the global nail services market in 2024–2025, which was accompanied by an increase in the number of sensitization episodes both in occupational settings and among end users. As a priority objective, the work establishes the systematization of current statistical and clinical information on the prevalence of allergic reactions to 2-hydroxyethyl methacrylate (HEMA), hydroxypropyl methacrylate (HPMA), and ethylene glycol dimethacrylate (EGDMA), as well as an analysis of the effectiveness of the existing regulatory approaches of the European Union. The methodological framework includes a comparative examination of data from multicenter audits, a systematic analysis of peer-reviewed sources, and a critical assessment of technical limitations and requirements articulated in ECHA and SCCS documents. The findings demonstrate a sustained upward trend in the proportion of sensitization to HEMA within the European population, reaching 1.98% by 2024, and also indicate an exceptionally high rate of occupationally mediated allergy among nail service professionals, reaching 78.8%. The stated provisions point to the insufficient effectiveness of current measures intended to restrict the use of the relevant monomers and confirm the necessity of a transition to polymerization technologies characterized by reduced sensitizing potential, taking into account the planned ban on the photoinitiator TPO in September 2025. The material has practical and regulatory significance for dermatological services, occupational health specialists, the chemical and technological sector of the cosmetics industry, and supervisory bodies responsible for monitoring the safety of mass consumer products.

Keywords: acrylates, sensitization, HEMA, HPMA, EGDMA, allergic contact dermatitis, nail industry, occupational diseases, occupational hygiene, cosmetic chemistry.

Introduction

The contemporary beauty sector is distinguished by accelerated technological transformation, with the most dynamically expanding domain being nail aesthetics. According to market estimates relevant to 2024–2025, the global turnover of nail care products is approximately 15.55 billion United States dollars and, along the projected growth trajectory, may reach 23.1 billion dollars by 2031 [1]. Such expansion is substantially sustained by stable demand for long-wearing polymer coatings (gel polishes) and systems for artificial nail modeling. At the same time, the widespread dissemination of (meth)acrylate-based solutions has generated a pronounced medical and social burden, manifested by a rise in allergic contact dermatitis (ACD), which is acquiring features of an epidemic phenomenon [2, 3].

Previously, the principal cohorts of acrylate sensitization were predominantly associated with dental practice and industrial manufacturing; however, within the 2021–2025 interval, a distinct shift in the epidemiological

profile has been documented: the beauty industry has become the leading channel of exposure to reactive acrylate compounds [4, 5]. From an immunopathogenetic perspective, a significant role in sensitization development is played by low-molecular-weight monomers characterized by high penetrative capacity and the ability to haptenize skin proteins, primarily 2-hydroxyethyl methacrylate (HEMA), hydroxypropyl methacrylate (HPMA), and ethylene glycol dimethacrylate (EGDMA) [7, 8].

Materials from 2024 indicate a continuing increase in the frequency of allergy to HEMA among patients referred for patch testing, reflecting growth in clinically significant sensitization. According to [2], the proportion of nail-associated ACD increased from 0.91% in 2016 to 1.98% in 2023, despite the operation of the restrictive provisions of European Union Regulation 2020/1682. The persisting research deficit is driven by insufficient elaboration of questions concerning the dynamics of cross-reactivity, as well as by limited data on the effectiveness of implementing products marketed as HEMA-free under conditions of modification of the chemical composition of photoinitiators and associated technological components [20-23].

The aim is to conduct a comprehensive epidemiological analysis of sensitization to the key acrylates (HEMA, HPMA, EGDMA) in the nail segment, with an emphasis on occupationally mediated risks and the regulatory changes of 2025.

Scientific novelty is determined by the synthesis of information on the presumed impact of new legislative restrictions (Omnibus VII) on the morbidity structure of acrylate-induced dermatitis in the realities of 2025.

The authorial hypothesis is formulated as the assumption that restrictions on the use of HEMA, in the absence of a revision of standards for personal protective equipment and under insufficient control of the circulation of household kits, will not ensure a reduction in the overall incidence of ACD due to pronounced cross-reactivity among acrylate monomers.

Materials and Methods

To achieve the stated aim, a multilevel methodological framework was developed that integrates quantitative and qualitative data-processing strategies. The methodological scaffold relied on a systems approach, enabling the examination of acrylate sensitization within an interdisciplinary plane that accounts for dermatological, toxicological, chemical-polymeric, and legal dimensions.

The research design included a systematic review of sources with an analysis of publications indexed in PubMed, Scopus, and Web of Science over the five-year period 2020–2025. A substantive component consisted of a comparative alignment of data corpora from multicenter European studies (EECDRG) with the results of regional clinical observations conducted across different jurisdictions (Greece, Israel, Canada, the Russian Federation). A separate block comprised a content analysis of technical and regulatory documentation, including examination of materials from the Scientific Committee on Consumer Safety (SCCS), regulatory documents of ECHA, as well as specifications from manufacturers of cosmetic raw materials that reflect composition, functional roles, and component limitations. In addition, a case study approach was applied, providing for an in-depth consideration of clinical episodes of occupational ACD among nail service specialists in order to identify typical exposure scenarios, factors of persistent sensitization, and the effectiveness of preventive measures.

The source corpus of the study was structured according to a typological principle. The principal share consisted of academic publications and clinical investigations, including patch-testing data, descriptions of haptenization mechanisms, and characterizations of epidemiological trends. The regulatory segment was represented by official reports and position documents from ECHA, SCCS, and HPRA, defining the legal status of acrylates and photoinitiators in 2024–2025. Additional empirical grounding was provided by industry analytical reviews, including materials from Mordor Intelligence and Technavio, used to characterize the parameters and dynamics of the nail market.

The theoretical interpretation of the results was based on the delayed-type hypersensitivity model (Type IV according to Gell and Coombs) as applied to low-molecular-weight haptenic compounds with a molecular mass below 500 Da, which allows an accurate description of the key stages of the allergen-specific, cell-mediated response upon contact with (meth)acrylates. In the block devoted to market determinants, indicators of CAGR (compound annual growth rate) were used for the gel-polish segment and for hypoallergenic systems, ensuring

comparability between demand trends and the dynamics of potential exposures.

Results and Discussion

Epidemiological monitoring data from recent years indicate that acrylates have become firmly established among the most clinically significant and highly reactogenic contact allergens, making a substantial contribution to the overall structure of allergic contact dermatitis. Materials from a large-scale EECDRG audit conducted across seven European centers demonstrate a sustained increase in the frequency of positive patch-test reactions to 2-hydroxyethyl methacrylate (HEMA) among patients evaluated for suspected ACD, which points to a growing prevalence of sensitization and an increase in diagnostically confirmed cases.

Table 1 below presents data on the prevalence of sensitization to HEMA and acrylate-associated ACD.

Table 1. Prevalence of sensitization to HEMA and acrylate-associated ACD (prepared by the author on the basis of [3]).

Study period	Total number of patients (n)	Positive reactions to HEMA (%)	Proportion of nail technicians within the allergic contact dermatitis case mix (%)	Primary source of exposure
2016–2017	12,045	0,95	34,2	Salon manicure
2018–2019	15,320	1,23	48,6	Salon-based and at-home manicure
2021–2022	19,810	1,52	56,8	At-home ultraviolet kits
2023–2024	26,297	1,98	67,3	Professional sector

The most unfavorable picture is observed in the occupational environment. Nail service specialists (nail technicians) operate under conditions of regular and prolonged exposure to monomeric components throughout the work shift, which creates prerequisites for chronic contact and subsequent sensitization. A 2024 study found that 78.8% of technicians reporting complaints related to the skin of the hands exhibited positive reactions to at least one acrylate during patch testing [9]. At the same time, it was shown that the probability of developing allergy in professionals exceeds the corresponding indicator among consumers by 12.7 times, reflecting a fundamentally different level of cumulative burden and contact frequency [9, 10].

The high allergenicity of the key monomers is determined by their physicochemical properties and structural features, which confer a pronounced capacity for cutaneous penetration and haptenization. For 2-hydroxyethyl methacrylate (HEMA), the molecular weight is 130 g/mol, consistent with the parameters of a low-molecular-weight hapten capable of traversing the stratum corneum under minimal exposure, including in situations of microdamage to the skin and contact with tissues of the periungual fold [8, 11]. Nevertheless, the totality of clinical observations and research evidence points to a multifactorial nature of sensitization in the nail sector: HEMA cannot be regarded as the sole causally significant agent. In a number of studies, hydroxypropyl methacrylate (HPMA) and ethylene glycol dimethacrylate (EGDMA) functioned as the leading allergens in a subset of patients whose reaction to HEMA remained negative, which underscores the necessity of expanded testing panels and consideration of cross-reactivity within the (meth)acrylate group [9] (see Fig. 1).

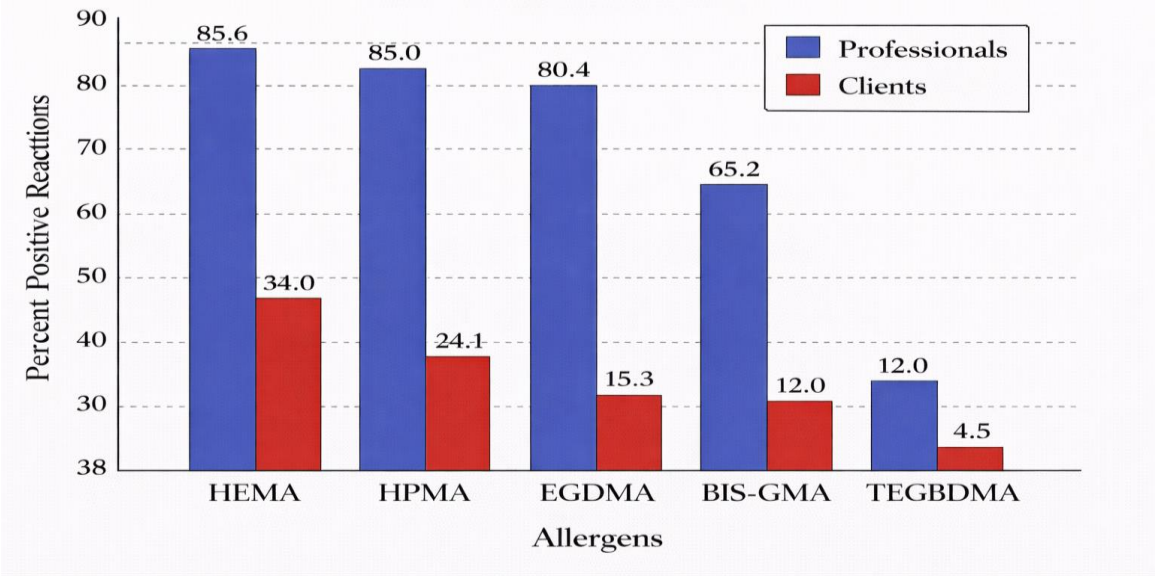

Fig. 1. Comparative frequency of sensitization to (meth)acrylates depending on the type of exposure (compiled by the author based on [6]).

Pronounced co-sensitization, manifested as simultaneous allergic reactivity to multiple representatives of the (meth)acrylate series, is largely determined by their structural proximity and shared reactive moieties. Following the development of a specific immune response to 2-hydroxyethyl methacrylate (HEMA), activated T lymphocytes are capable of recognizing antigenic determinants of similar molecules, including hydroxypropyl methacrylate (HPMA) and ethylene glycol dimethacrylate (EGDMA), which is clinically realized as cross-reactivity and an expanded spectrum of causally significant allergens [7, 12]. Under such conditions, an isolated substitution of one monomer with another within conventional acrylic systems does not reduce the allergenic burden and cannot be regarded as a comprehensive preventive strategy [7, 17].

The particular vulnerability of the occupational group is further intensified by limitations of standard personal protective equipment. It has been shown that methacrylates are able to permeate nitrile gloves of standard thickness (3 mil) in less than 30 minutes, rendering routinely used barrier measures insufficient under prolonged or repeated exposure [19]. Continued work while wearing gloves contaminated with monomers often produces an occlusion effect: increased hydration of the stratum corneum and local maceration facilitate enhanced transdermal absorption and potentiate sensitization, effectively converting the barrier into a factor that accelerates allergen penetration.

The clinical spectrum of ACD among nail service specialists is characterized by polymorphism and a tendency toward chronicity. Chronic inflammatory involvement of the fingertip pads with painful fissures and marked hyperkeratosis is frequently described, designated as chronic pulpitis [4]. Periungual dermatitis is also a common presentation, encompassing swelling and erythema of tissues surrounding the nail plate, reflecting the typical localization of contact with materials and polymerization products [18, 19]. Additionally, distal onycholysis is noted—the separation of the nail plate from the nail bed—which in practical settings is often interpreted as a mycotic lesion; this increases the risk of diagnostic error and delays the institution of appropriate anti-allergic management [1].

Figure 2 presents a hierarchy of risk factors for the development of acrylate-induced ACD.

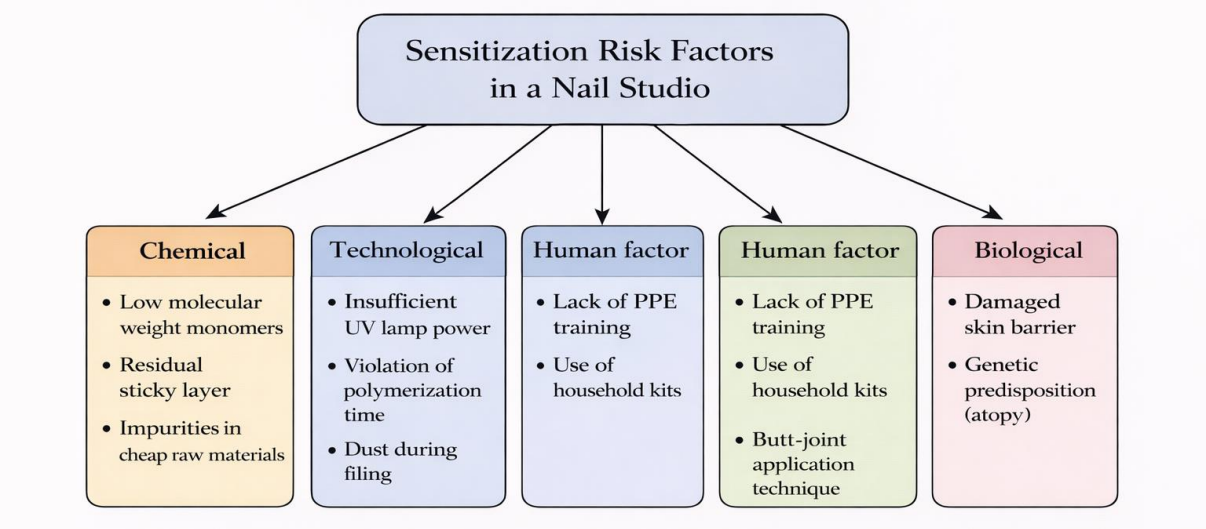

Fig. 2. Hierarchy of risk factors for the development of acrylate ACD (author's data).

In turn, Table 2 provides a more detailed description of the comparative characteristics of existing barriers and the effectiveness of personal protective equipment against acrylates.

Table 2. Comparative characteristics of barriers and the effectiveness of personal protective equipment against acrylates (prepared by the author on the basis of [15, 16, 19]).

Type of protection	Effectiveness against HEMA	Limitations	Recommendations
Nitrile gloves (3 mil)	Low (penetration <30 min)	Rapid polymer degradation	Not recommended for prolonged work
Nitrile gloves (6-8 mil)	Medium	Reduced tactile sensitivity	Mandatory replacement every 45-60 min
Protective masks (KN95/FFP2)	High (against dust)	Do not protect against monomer vapors	Use during filing and grinding
Local exhaust ventilation	High	Dependence on power and filters	Capture source directly at the worktable

A pivotal regulatory shift in 2024–2025 was the decision adopted by the European Commission within the Omnibus VII package to prohibit the photoinitiator Trimethylbenzoyl diphenylphosphine oxide (TPO) [21]. This compound has been classified as CMR 1B due to reproductive toxicity; consequently, as of 1 September 2025, products containing TPO are subject to complete withdrawal from circulation within the European Union. This creates simultaneous regulatory and technological pressure for manufacturers: the need to minimize or eliminate HEMA because of its sensitizing potential, while concurrently removing TPO on the grounds of systemic toxicological significance. A likely response to the new constraints is considered to be an accelerated transition to alternative photoinitiators (in particular, TPO-L or phenyl ketone derivatives), as well as to oligomeric systems with higher molecular weight, such as Di-HEMA TMHDC, which are characterized by a reduced capacity for transdermal penetration [24].

Against the backdrop of strengthened regulatory oversight and increasing vigilance within the professional environment, an expansion of the product segment labeled as HEMA free is observed. At the same time, clinical observations and 2024 data indicate the fundamental limitations of this labeling as a safety criterion: the absence of HEMA in the composition is not equivalent to a reduced risk of sensitization or to the exclusion of allergic contact dermatitis [9, 13]. Formulation practices often amount to a functional replacement of HEMA with HPMA or other (meth)acrylates that may be absent from standard

diagnostic patch testing panels; as a result, the causally significant allergen remains unidentified, and the clinical presentation is interpreted as idiopathic or is erroneously attributed to unrelated factors [9, 14]. An additional pathogenetically meaningful circumstance is incomplete polymerization: residual monomers in alternative systems, while retaining high reactivity, may demonstrate comparable and, in certain situations, no lesser aggressiveness toward the cutaneous barrier, sustaining inflammation and amplifying sensitization even when the product is declared hypoallergenic.

Conclusion

An epidemiological assessment of sensitization to (meth)acrylates (HEMA, HPMA, EGDMA) over 2020–2025 indicates the emergence of a systemic occupational health crisis in the nail industry, characterized by a sustained increase in allergic contact dermatitis and an expansion of high-risk cohorts. The objective of organizing data on allergy prevalence has been achieved: an increase in indicators in the general tested population to approximately 2% has been documented, alongside attainment of extremely high values in the professional cohort of nail technicians, up to 79%.

The results obtained are consistent with the initial hypothesis: the restrictions on the use of HEMA introduced in 2021 did not yield a clinically meaningful reduction in ACD frequency, which is explained by pronounced cross-reactivity with HPMA and EGDMA, as well as by the ongoing uncontrolled circulation and use of household kits that sustain exposure outside professional regulations. The exceptional vulnerability of nail technicians as the leading risk group is additionally confirmed; key determinants include insufficient barrier effectiveness of standard-thickness gloves and incomplete polymerization of materials during the use of UV lamps, which increases the share of residual monomers and intensifies the sensitizing burden. From a regulatory perspective, the prohibition of TPO in September 2025 is regarded as a factor capable of accelerating large-scale technological restructuring of the sector and stimulating a transition to more stable and toxicologically substantiated chemical formulations aimed at reducing residual monomer content and diminishing allergenic potential.

The practical component of the conclusions indicates the necessity of institutionalizing preventive measures, including mandatory training in the non-touch technique, the use of higher-density gloves (6–8 mil), and regular technical maintenance of photopolymerization lamps to ensure adequate polymerization and minimize exposure. The presented provisions have applied significance for the advancement of preventive dermatology and for the refinement of cosmetic product safety standards aimed at reducing the burden of occupationally mediated dermatoses within the beauty industry.

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