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Prevention and Treatment of Nail Damage after Frequent Use of Decorative Coatings

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Abstract

Against the backdrop of the rapid expansion of the nail care market, a commensurate rise in the frequency of associated dermatological disorders is being recorded, which confers high significance to the investigation. The aim of the work is to organize current knowledge on the etiopathogenesis of injuries to the nail apparatus induced by decorative coatings and, on this basis, to develop prevention and treatment recommendations for top-tier specialists. Methodologically, the study relies on a systematic review of publications from the last five years in the Scopus and Web of Science databases, with a targeted focus on dermatology, immunology, toxicology, and materials science. The results of the analysis indicate that the leading drivers of the epidemiology of allergic contact dermatitis (ACD) are (meth)acrylate monomers, above all 2-hydroxyethyl methacrylate (HEMA). A synergy of damaging effects is demonstrated: prior mechanical preparation of the nail plate potentiates the chemical aggressiveness of monomers. The risk of UV-induced carcinogenesis of the skin of the hands when using polymerization lamps is assessed as low; however, it necessitates adherence to precautions. The practical conclusions emphasize the need to integrate an understanding of pathophysiological processes into working protocols with the aim of minimizing adverse outcomes and improving the quality of client counseling. The material is addressed to practicing nail service technicians, beauty industry educators, and dermatologists who manage patients with cosmetically induced nail lesions.

Keywords: *Allergic Contact Dermatitis, (Meth) Acrylates, HEMA, Onycholysis, Thinning of the Nail Plate, Chemical Burn, UV Nail Lamps, Smart-Pedicure, Prevention of Nail Damage, Nail Cosmetics.*

INTRODUCTION

The global nail service sector demonstrates steady expansion, and this dynamic is statistically associated with growth in occupationally induced and consumer dermatoses [1]. A body of empirical observations from recent years confirms the scale of the problem: up to 12.4% of professionals report cutaneous manifestations related to occupational exposure, whereas among practitioners seeking dermatologic care, in 79.4% a diagnosis of allergic contact dermatitis (ACD) is established [3]. These data reflect a transformation of the risk profile: whereas mechanical injuries and irritant reactions to components of traditional polishes previously predominated, in current practice the key phenomenon is widespread chemical sensitization driven by the specific formulations of modern gel and acrylic systems [5].

Despite the abundance of applied techniques for nail strengthening and modeling, a pronounced methodological vacuum persists: there is no consolidated academic resource aimed at a professional but non-medical audience that would integrate data on the immunopathology of contemporary sensitizers, the biomechanics of device-induced trauma, and the photobiology of curing lamps.

The author's hypothesis is that a holistic understanding of these etiopathogenetically interconnected factors is a necessary prerequisite for designing effective and low-risk protocols in advanced nail service practice.

The aim of the study is to analyze and synthesize current scientific knowledge on the pathogenesis, prevention, and treatment of injuries to the nail unit associated with modern decorative coatings.

The scientific novelty lies in the first comprehensive examination of the synergistic influence of chemical, mechanical, and physical risk factors in contemporary nail service practice, with the development of evidence-based protocols for specialists.

MATERIALS AND METHODS

The present study was performed within the paradigm of a systematic literature review (systematic literature review). Selection of relevant publications was carried out in the

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international abstracting and full-text databases Scopus, Web of Science, PubMed, and Google Scholar for 2019–2024. The search strategy was formed by combining the following key expressions: allergic contact dermatitis, (meth)acrylates, HEMA, onycholysis, nail plate thinning, UV nail lamps, nail cosmetics.

The empirical basis comprised academic sources grouped into the following typological blocks:

1) Clinical and epidemiological studies: peer-reviewed publications in leading dermatology journals with data on prevalence, clinical phenotypes, and patch-testing results in ACD and other nail pathologies associated with cosmetic procedures.

2) Experimental and review articles: works elucidating the pathophysiological mechanisms of dermatologic conditions (including type IV hypersensitivity and the pathogenesis of chemical burns) and the principles of action of cosmetic ingredients.

3) Technical and toxicological reports: official safety assessment documents and substance safety data sheets (for example, for methacrylic acid), as well as analyses of UV-lamp emissions.

The theoretical and methodological framework of the immunopathological analysis relies on fundamental studies of delayed-type hypersensitivity reactions. The practice-oriented part devoted to allergens is based on data from large-scale patch-testing series. The discussion of device-based techniques and safety protocols is formed with consideration of advanced podological practice and the results of domain-specific safety assessments.

Studies demonstrate that the most thoroughly investigated area is allergic contact dermatitis associated with acrylates, whereas physical, phototoxic, and infectious complications are covered less comprehensively. There are contradictions between data on decreasing concentrations of sensitizing substances and the continuing rise in incidence. The following topics remain insufficiently studied:

- long-term effects of UV lamps,

- the impact of new generations of coatings on nail structure,

- the real-world effectiveness of preventive strategies in salon settings.

In addition, issues of the economic burden on healthcare and regulatory gaps in product labeling and certification are practically unexplored. Thus, a further comprehensive approach is required — from clinical dermatology to toxicology and regulatory policy.

RESULTS AND DISCUSSION

Modern decorative nail coatings can damage the nail plate via three fundamental pathogenetic trajectories: chemical, mechanical, and physical. These factors rarely act in isolation; rather, they mutually potentiate one another, producing synergistic harm. For example, aggressive filing that leads to thinning of the nail plate and loss of its barrier function facilitates transungual and periungual penetration of chemical allergens and irritants into deeper layers and surrounding tissues, increasing the likelihood and severity of chemically induced lesions [22].

Allergic contact dermatitis (ACD) to (meth)acrylates. ACD is a key chemical hazard in the modern nail industry. In recent years, there has been a shift from the previously dominant allergens—toluensulfonamide-formaldehyde resin (TSFR), characteristic of traditional polishes—to (meth)acrylate monomers underpinning gel and acrylic systems [23]. The most significant sensitizer is recognized as 2-hydroxyethyl methacrylate (HEMA), which in sensitized individuals yields positive patch-test results in 90–100% of cases. Frequent allergens also include 2-hydroxypropyl methacrylate (HPMA) and ethylene glycol dimethacrylate (EGDMA) [5].

The clinical spectrum of ACD is heterogeneous and encompasses both local and distant (ectopic) manifestations. Typical are periungual eczema (inflammation of the skin around the nail), pulpitis with painful fissures of the finger pads, as well as dystrophic changes of the nail plate [5]. Of particular clinical importance are ectopic reactions on the face, eyelids, and neck arising from transfer of unreacted monomers by the hands [7]. Pathophysiologically, ACD represents a delayed-type hypersensitivity reaction (type IV) that proceeds in two sequential phases (see Fig. 1) [10].

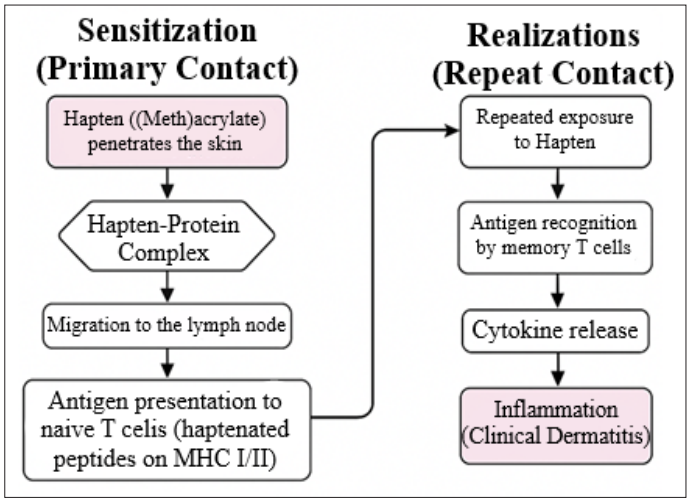

Fig. 1. Scheme of the pathophysiology of type IV hypersensitivity reaction to (meth)acrylates (compiled by the author based on [10, 11]).

Sensitization to (meth)acrylates is irreversible and is associated with pronounced long-term consequences. Induced memory T cells persist in the body for life. It follows that in a client or technician who has once been sensitized, subsequent contact with medical materials containing related acrylate compounds — dental composites, bone cement for endoprosthetics, surgical adhesives, components of diabetic devices — may provoke a severe allergic reaction [5]. Thus, the professional responsibility of a nail service

specialist extends beyond purely cosmetic safety and affects the client's long-term medical history.

Irritant contact dermatitis and chemical burns. Unlike ACD, irritant (simple) contact dermatitis is not immune mediated but represents a direct cytotoxic response of the skin to a chemical agent. The main irritants in nail services include methacrylic acid–based primers and solvents. Methacrylic acid is a strong organic acid that, upon contact with the skin, induces protein coagulation and, consequently, direct tissue injury [13]. The clinical spectrum varies depending on concentration and exposure time: from mild irritation to second-degree chemical burns with blister formation and foci of necrosis [12]. Solvents such as acetone and ethyl acetate defat the skin and nail plate, disrupt the lipid barrier, and thereby cause dryness, brittleness, and increased susceptibility to other irritants and allergens [23]. Table 1 presents a comparative analysis of the chemical composition and allergenic risks of nail coating systems.

Table 1. Comparative analysis of the chemical composition and allergenic risks of nail coating systems (compiled by the author based on [7, 12, 13, 23]).

Type of coating	Main components	Key allergens/irritants	Associated risks
Traditional nail polish	Nitrocellulose, TSFR, plasticizers (dibutyl phthalate), solvents (ethyl acetate, toluene)	Toluene sulfonamide-formaldehyde resin (TSFR), formaldehyde, solvents	ACD (historically), irritant dermatitis, nail plate staining
Gel polish	(Meth)acrylate oligomers/monomers (HEMA, Di-HEMA), photoinitiators (benzophenone)	HEMA, HPMA, EGDMA and other (meth)acrylates	ACD (high risk), irritant dermatitis, photoallergic dermatitis
Acrylic system	Powder (polymethyl methacrylate), liquid (ethyl methacrylate monomer), primer (methacrylic acid)	Methacrylate monomers, methacrylic acid (irritant)	ACD, irritant dermatitis, chemical burns, paresthesias
Dip powder	Powder (acrylic polymer), adhesive activator (cyanoacrylate)	Cyanoacrylates, acrylic powder	ACD (risk lower than gels but present), irritant dermatitis

Next, within the scope of this article, we address mechanical and physical damage. We begin with thinning and dystrophy of the nail plate. The nail plate is a highly ordered array of approximately 25 layers of cornified onychocytes [12, 18, 25]. Any aggressive mechanical treatment, especially with files of abrasive grade below 180 grit, results in physical removal of the dorsal (surface) layers. The consequences are a reduction in thickness, loss of stiffness, and disruption of the structural integrity of the plate [12]. Repeated cycles of application and removal of coatings with intensive filing cause a cumulative reduction in thickness, rendering nails more pliable and vulnerable to damage.

Traumatic onycholysis — separation of the plate from the nail bed — often develops via a lever mechanism when excessively long sculpted nails are worn or during forceful, improper removal of the coating [12]. The resulting subungual space serves as a favorable niche for secondary microbial colonization, most commonly Pseudomonas aeruginosa (characteristic green discoloration) and Candida albicans [14, 16]. Brittleness (brittle nails) presents with two principal phenotypes: onychoschizia — horizontal delamination of the free edge, and onychorrhexis — longitudinal fissures and ridges. Both forms are exacerbated by repeated exposure to dehydrating solvents and mechanical trauma [4, 8, 9]. Keratin granulations represent whitish, rough areas on the plate surface arising from disruption of the superficial keratin layers during polish removal [2, 12].

Polymerization of gel coatings is performed using lamps that emit predominantly in the UVA range of 365–405 nm. Concerns regarding the carcinogenic potential of this radiation are not unfounded: experiments in cell cultures demonstrate the ability of nail-lamp radiation to induce DNA damage and mutagenesis in keratinocytes; isolated clinical observations of squamous cell carcinoma of the skin of the hands have been reported in users with a longstanding history of gel manicures. At the same time, according to dosimetric estimates, under typical salon use — brief sessions and irregular exposure — the overall risk of developing skin cancer is considered low [6, 14]. It should be remembered that there is substantial inter-model variability in lamp power and spectrum, as well as lifetime dose accumulation, which contributes to photoaging of the skin of the hands [15, 17, 20] (fig.2).

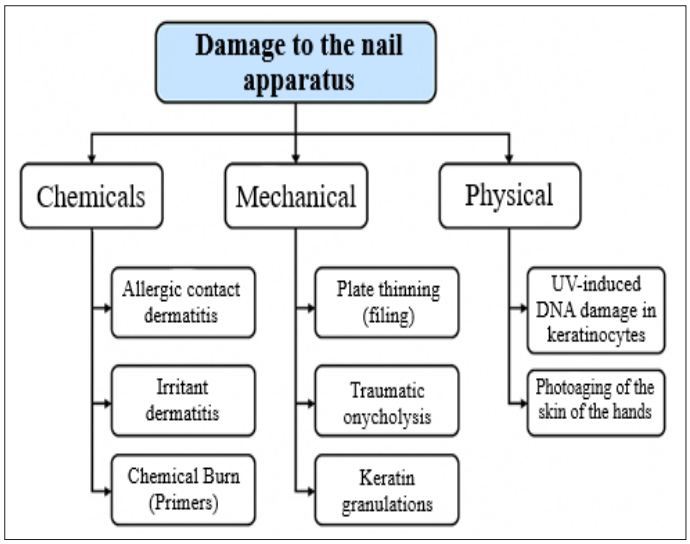

Fig. 2. Classification of damage to the nail apparatus by etiological factor (compiled by the author based on [15, 17, 20]).

If we turn to current approaches to prevention and treatment, the principal strategy for preventing ACD is to maximize limitation of skin contact with unreacted monomers. This is achieved through strict adherence to the no-touch technique, in which the practitioner avoids contacting the client's skin with a tool or a brush carrying the material. Standard nitrile gloves do not provide an adequate barrier function: (meth) acrylate monomers diffuse through them within a few minutes. It is preferable to use double gloving or specialized gloves made of butyl rubber or laminate type 4H, which is particularly important during prolonged manual contact with the materials [24, 25].

Smart pedicure as a risk-reduction method. Smart pedicure device-based, dry is a modern technology based on the use of a rotary instrument without prior soaking of the feet. From an evidence-based practice standpoint, this format reduces the risk profile in several respects. First, complete avoidance of water procedures eliminates exposure to waterborne pathogens for example, Mycobacterium fortuitum, associated with furunculosis and decreases the likelihood of skin maceration, which is critical for clients with diabetes or peripheral perfusion disorders [19]. Second, device-assisted processing ensures precise, titrated removal of hyperkeratosis corns, calluses with minimal trauma to intact tissues, in contrast to blades and rigid files applied to softened skin [18, 21].

Protection against UV radiation. Although consensus regarding carcinogenic risks remains limited, reasonable precaution entails limiting the cumulative UV dose. In practice, this is achieved by applying a broad-spectrum sunscreen with SPF 30+ to the client's hand skin 20 minutes before the procedure or by using special fingerless gloves with UV-blocking properties [14].

Regarding therapeutic and restorative approaches, the only pathogenetically grounded strategy for treating ACD remains complete and strict avoidance of contact with the causally significant allergen and chemically related compounds [6]. In onycholysis, priority measures include regular trimming of the detached portion of the nail plate, maintaining dryness of the affected area, refraining from mechanical cleaning under the nail, and using topical antiseptics for example, 2% thymol in chloroform to prevent secondary infection [26].

To improve the structure and mechanical strength of damaged nails, a number of active ingredients with varying degrees of evidentiary support are used see Table 2.

Table 2. Evidence-based efficacy of active ingredients for nail restoration (compiled by the author based on [14,18, 21, 26]).

Active ingredient	Mechanism of action	Clinical indication	Level of evidence
Biotin (Vitamin B7)	Participates in keratin synthesis, improves onychocyte structure.	Idiopathic brittle nails (increases thickness by ~25%).	Moderate (small clinical studies). Recommended dose 2.5 mg/day.
Panthenol (Provitamin B5)	Acts as a humectant, attracting and retaining water in the nail plate.	Dryness, loss of elasticity, brittleness.	Limited (mostly in vitro studies). Improves hydration and flexibility.
Hyaluronic acid	A potent humectant, moisturizes the nail plate and cuticle.	Dryness, brittleness, cuticle damage.	Low (clinical data are limited, but the mechanism of action is plausible).
Hydrolyzed keratin	Fills microcracks and irregularities on the nail surface, creating a protective film.	Superficial damage, onychoschisis.	Cosmetic effect (temporary improvement in appearance, does not treat).

Delineation of professional competencies. A nail service specialist must clearly understand the boundaries of their professional role: nail specialization is limited exclusively to aesthetic care for healthy nails and skin [20, 21]. When signs are identified that go beyond a cosmetic defect (suspected fungal infection, pronounced eczema, paronychia with purulent discharge, onycholysis of unclear etiology), the procedure must be discontinued, and the client should be strongly referred for consultation with a dermatologist or a podologist to establish the diagnosis and prescribe therapy [24, 27]. Any self-initiated attempt to treat or diagnose diseases lies outside the legal scope of practice and potentially endangers the client's health.

Thus, damage to the nail apparatus proceeds along chemical, mechanical, and physical trajectories that mutually amplify one another through the loss of the barrier function of the thinned plate. The allergenic focus has shifted to (meth) acrylates, primarily HEMA; sensitization is irreversible and clinically significant because of cross-exposures in medical applications. Irritant lesions are caused by methacrylic acid and solvents; mechanical aggression (filing with <180 grit, forceful removal, excessive length) leads to thinning, onycholysis, and colonization by Pseudomonas/Candida; UV-A exposure is genotoxic in vitro with a low expected risk under typical regimens, but cumulatively significant. The most effective prevention consists of a strict no-touch technique, gloves with a proven barrier (double/butyl rubber/laminate), dry smart pedicure, photoprotection; therapeutically, complete elimination of causal (meth) acrylates and conservative management of onycholysis; biotin has moderate evidence, other ingredients provide a predominantly cosmetic effect. In practice, multilevel risk management and strict delineation of competencies with early referral to a dermatologist are necessary; unresolved issues include standardization of glove barriers and the long-term carcinogenicity of lamps.

CONCLUSION

A comprehensive appraisal of findings from other studies has made it possible to state a number of fundamental propositions with direct applied significance for nail service specialists. The key chemical risk factor in the modern industry is an epidemiological surge of allergic contact dermatitis driven by the widespread use of (meth) acrylate monomers; hence the need for strict regulation of procedures that minimize the contact of compositions with the skin. A cumulative-synergistic nature of damage has been established: mechanical traumatization of the nail plate potentiates chemical exposure, which underscores the requirements for atraumatic techniques of apparatus-based processing. Advanced technologies, including smart pedicure, demonstrate a shift toward preventive, scientifically validated practice aimed at reducing occupational risks.

Consequently, the goal — the systematization of relevant knowledge for practitioners — has been achieved. The material presented performs a translational function between clinical research and salon routine, providing practitioners with an instrumentarium for well-founded decision-making. The practical significance lies in a rethinking of the professional role: the modern nail service professional is not only an artist but also a risk manager with deep competence in materials science, chemistry, and the fundamentals of dermatology. Promising avenues for further inquiry involve the development of low-sensitizing monomer systems and the standardization of the technical parameters of UV/LED lamps in the interest of enhancing industry safety.

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