



Microbiological Risks and Dermatological Consequences of Aqueous Maceration in Manicure Practice: Rationale for Transition to Waterless Hardware Techniques

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Abstract

*The study provides a comprehensive analysis of the risks associated with the traditional practice of soaking hands (maceration) in manicure procedures and a scientific rationale for transitioning to modern waterless hardware technologies. The introduction emphasizes the relevance of the topic in the context of the rapid growth of the global nail-care services market and the tightening of biosafety requirements. The aim of the present research is to argue for the abandonment of aqueous maceration in manicure by systematizing and analyzing the risks of cross-contamination and disruption of the skin barrier, as well as to present evidence of the advantages of waterless hardware techniques, illustrated by a case study. The methodological framework includes a systematic review of peer-reviewed sources, a content analysis of regulatory acts and industry reports, and an in-depth case study of the advanced waterless technique E-File Dry Manicure. The results demonstrate that water in manicure bowls acts as a vector for pathogens, in particular *Pseudomonas aeruginosa*, and creates conditions for the development of onychomycoses, whereas maceration disrupts the barrier properties of the skin, increasing its susceptibility to damage and infection. An analysis of regulatory enforcement practice reveals systemic gaps in monitoring compliance with sanitary standards. As a practical solution, E-File Dry Manicure is proposed as a safe and atraumatic alternative, whose effectiveness is supported by professional recognition and sustained market demand. The conclusions confirm the hypothesis of the superiority of waterless methods and contain targeted recommendations for practicing specialists, educational institutions, and regulatory bodies. The information contained in the study will be of interest to nail-care professionals, educators, salon owners, and representatives of regulatory structures in the beauty industry.*

Keywords: Maceration, Hardware Manicure, Salon Safety, *Pseudomonas Aeruginosa*, Onychomycosis, Skin Barrier Function, E-File Dry Manicure, Professional Standards, Nail-Care Service, Infection Control.

INTRODUCTION

The professional beauty services industry demonstrates steady and incremental expansion. According to analysts, the global nail salon services segment in 2024 generated revenue of \$12,01 billion, and by 2029 it is expected to grow to \$17,89 billion at a compound annual rate of 8,4% (CAGR) [1]. This trajectory is driven by a transformation of consumer expectations: the contemporary audience demands not only impeccable visual outcomes but also demonstrable procedural safety and hygiene. Under these conditions, long-standing technologies that have been perceived as the industry standard require critical reappraisal through the lens of current scientific evidence. Among such routine practices is pre-manicure hand immersion in water (maceration).

Despite its apparent harmlessness, this manipulation is associated with several types of risks. Water used in salon settings, when insufficiently treated, can act as a reservoir and a transport medium for the transmission of a broad spectrum of pathogens—bacterial and fungal agents capable of initiating infections of the nail plate and periungual tissues [2, 3]. From a dermatological standpoint, prolonged contact with water induces maceration of the stratum corneum, which weakens its barrier properties and increases skin permeability to microbial agents and chemical irritants [4, 5].

The key scientific deficit lies in the absence of an integrated academic investigation that systematically links the microbiological and dermatological hazards induced by maceration in manicure practice with an assessment of the

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safety and effectiveness of modern waterless (dry) hardware approaches as an alternative technological paradigm. Existing studies typically either address specific pathogens or discuss general salon hygiene regulations, without providing a structured analysis of maceration itself as an independent risk factor.

The aim of this study is to justify the abandonment of water maceration in manicure by systematizing and analyzing the risks of cross-contamination and disruption of the skin barrier, as well as to present evidence of the advantages of waterless hardware techniques, illustrated by a case study.

The scientific novelty lies in the first comprehensive synthesis of data from microbiology, dermatology, and regulatory practice to substantiate a shift in the technological standard of nail services from aqueous to waterless methods.

The author's hypothesis is that abandoning maceration and implementing professional waterless hardware protocols (for example, E-File Dry Manicure) radically reduces the likelihood of infectious and dermatological complications, enhances the safety profile, and improves the quality of manicure services, in compliance with contemporary sanitary and hygienic requirements and key market development trends.

MATERIALS AND METHODS

This study was conducted within the logic of an interdisciplinary inquiry that integrates tools from adjacent fields of knowledge to comprehensively examine the stated issues. The methodological framework includes a systematic literature review, content analysis of regulatory and technical acts, examination of industry reports, and case study analysis.

The systematic review was aimed at establishing the theoretical and empirical foundation of the research. The sample included peer-reviewed publications from the last five years retrieved from the international databases Scopus, Web of Science, and PubMed. The search strategy was built on the key queries *Pseudomonas aeruginosa* nail infection, onychomycosis risk factors, skin barrier function maceration, and occupational dermatology nail salon. This design made it possible to reconstruct the current state of knowledge on water-associated pathogens, their transmission routes, determinants of nail unit infection risk, and the pathophysiological mechanisms triggered by prolonged hyperhydration of the skin.

The content analysis of the regulatory and technical framework was oriented toward identifying existing standards and recommendations on hygiene and safety in the beauty industry. Considered were guidance documents and standards developed by specialized health and occupational safety institutions, including the Centers for Disease Control and Prevention (CDC) and the Occupational Safety

and Health Administration (OSHA). Additionally, to assess law-enforcement practice, publicly available reports on identified violations published by governmental regulators were examined, using materials from the Texas Department of Licensing and Regulation (TDLR) as an example.

The analysis of industry reports was employed to reconstruct the market context and to capture the key development trajectories of the nail service segment. Materials from leading analytical providers, primarily The Business Research Company, served as the empirical base, which enabled a quantitative assessment of the global market size, the construction of forecast scenarios for its dynamics, and a description of consumer demand structure, including the growing client orientation toward safety and hygiene indicators.

The case study method was applied to verify theoretical propositions using a specific professional case. A detailed analysis was conducted of production practice, an authorial technique, and the results of the activities of a leading master-instructor as well as a judge of international championships. This tool-intensive analysis demonstrated the successful implementation, high level of safety, and pronounced market attractiveness of the waterless hardware technology E-File Dry Manicure, along with its economic and professional advantages for specialists.

The source base is structured into three complementary clusters:

- 1) academic studies that form the scientific core and evidentiary platform on microbiological and dermatological aspects;
- 2) official regulatory documents and reports that reflect current standards and the practice of their compliance;
- 3) analytical industry overviews that provide an understanding of the socioeconomic context of the issues under consideration.

RESULTS AND DISCUSSION

Traditional manicure with preliminary soaking of the hands creates conditions in which water serves not only as a preparatory component but also as a potential reservoir and transport medium for pathogenic microorganisms. An analytical review of scientific publications records a number of key risks directly associated with the introduction of aqueous steps into salon practice.

The central bacterial agent consistently associated with the water environment of nail services is *Pseudomonas aeruginosa* — a Gram-negative microorganism with a broad ecological niche (soil, freshwater bodies, plant substrates) [6]. As an opportunistic human pathogen, it is the leading cause of green nail syndrome (chloronychia), clinically manifested by discoloration of the nail plate into green, green-yellow, or green-black tones due to the production

of characteristic pigments, pyoverdine and pyocyanin [2,3]. Research data consistently demonstrate that colonization by *P. aeruginosa* is facilitated by chronic exposure to water, soap, and detergents, as well as microtraumatization of the structures of the nail apparatus [6, 7]. Consequently, both clients and technicians whose professional activity involves constant contact with water logically fall into the high-risk group [4, 5].

The issue is not limited to the mere presence of bacteria in tap water: critical is the synergy of two factors induced by the maceration procedure itself. First, organic substrates (epidermal fragments, subungual contaminants) inevitably enter the warm manicure bath, forming a nutrient medium. Second, such a medium is optimal for the proliferation of *P. aeruginosa*. As a result, a step conceived as hygienically cleansing can in fact become an incubational and contaminating process that actively creates prerequisites for colonization followed by infection.

In addition to bacterial risks, a warm and humid environment predisposes to fungal nail infections, onychomycoses. This is one of the most prevalent disorders of the nail unit, accounting for up to 50% of all onychopathies [3]. Excess moisture is a key trigger: it leads to skin maceration and creates optimal conditions for the growth of dermatophytes, primarily *Trichophyton rubrum*.

Cross-transmission in salon settings occurs via contaminated footbaths and instruments that are regularly immersed in water. *P. aeruginosa* and other microorganisms can form biofilms on work surfaces, stable microbial consortia shielded by a polysaccharide matrix. This organization confers increased tolerance to standard disinfectants, complicates their elimination, and consequently amplifies the risk of transmission from client to client even with formal adherence to cleaning protocols. Table 1 presents systematized data on the principal pathogens associated with the aquatic environment in nail salons.

Table 1. Pathogenic microorganisms associated with the aquatic environment in nail salons (compiled by the author based on [2-6]).

Pathogen	Type	Primary route of transmission in the salon	Clinical manifestations
<i>Pseudomonas aeruginosa</i>	Bacterium	Contaminated manicure baths, nonsterile instruments, humid environment	Chloronychia (green nail syndrome), paronychia, onycholysis
<i>Trichophyton rubrum</i>	Fungus (dermatophyte)	Humid environment promoting growth; contaminated surfaces and instruments	Onychomycosis (discoloration, thickening and deformation of the nail plate, onycholysis)
<i>Staphylococcus aureus</i>	Bacterium	Contact with contaminated surfaces, microtrauma of the skin	Paronychia (inflammation of the periungual fold), abscesses, impetigo
<i>Klebsiella</i> spp.	Bacterium	Contaminated manicure baths and water	Bacterial infections of the nails and skin, especially in immunocompromised individuals

Beyond the direct microbiological threat, maceration adversely affects the physiology of the skin, undermining its innate defense mechanisms. The stratum corneum of the epidermis is the central element of this defense: it forms a physical barrier, regulates transepidermal water loss and limits transcutaneous penetration of exogenous substances and microorganisms [5, 8].

Prolonged contact with water induces hyperhydration of the stratum corneum. Corneocytes increase in volume, and the ordered arrangement of intercellular lipid bilayers, critical for barrier function, becomes disorganized. This process, maceration per se, leads to a marked increase in transepidermal water loss (TEWL) after the skin dries, indicating barrier injury. The weakened barrier becomes more permeable not only to water but also to pathogens and low-molecular-weight chemical allergens present in cosmetic formulations [5, 9].

Another key protective element is the acid mantle: a thin surface film with an acidic reaction (pH 4–6) that suppresses the growth of potentially pathogenic microflora and provides optimal conditions for the enzymes involved in lipid synthesis and in the regulated desquamation process [5]. Tap water generally has a neutral or slightly alkaline pH (≈ 7 and above) and, upon contact, transiently neutralizes the acid mantle. Although the skin has buffering capacity and can restore its acidity, frequent and prolonged exposure to an alkaline environment diminishes this compensatory potential and creates a window of vulnerability that favors colonization of the skin surface by microorganisms that prefer neutral or alkaline conditions, including *P. aeruginosa*.

Thus, maceration triggers a dangerous synergy: it simultaneously increases the likelihood of pathogen introduction and dismantles the natural lines of defense,

both the physical barrier of the stratum corneum and the chemical barrier of the acid mantle. This is a double blow to client safety that renders traditional water-based procedures fundamentally unsafe. Eliminating water breaks this vicious

circle from both sides: the route of infection transmission disappears and the structural and functional integrity of the skin barrier is preserved. The mechanism of barrier injury is schematically shown in Figure 1.

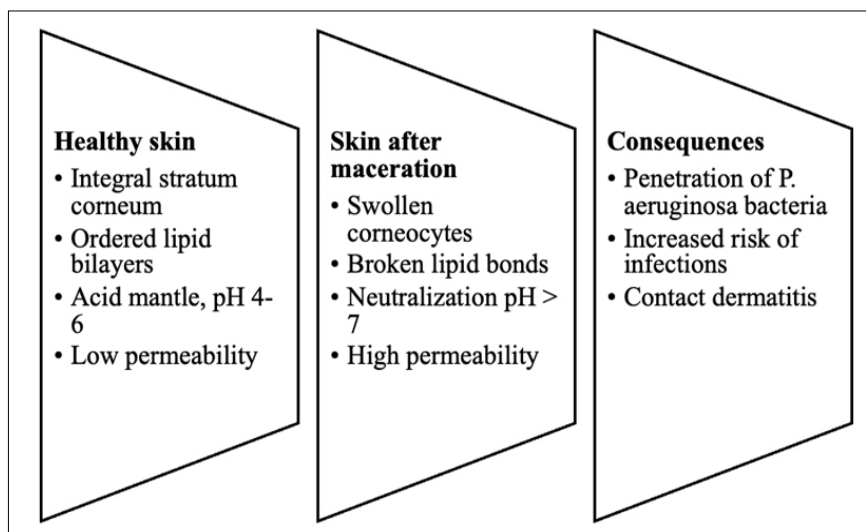


Fig. 1. The mechanism of damage to the epidermal barrier during maceration (compiled by the author based on [5; 8-10]).

Despite the presence of detailed sanitary and hygienic regulations, their implementation in nail service practice encounters persistent organizational and behavioral barriers. U.S. sectoral regulators—OSHA and CDC—set forth strict infection control algorithms that mandate obligatory cleaning and disinfection of reusable instruments, work surfaces, and equipment after each client [4]. However, the effectiveness of these prescriptions is critically determined by the human factor—the degree of meticulousness and personal responsibility of technicians and salon owners.

Empirical data from inspection activities confirm the scale of the problem. According to summaries from the Texas Department of Licensing and Regulation (TDLR) for Harris

County for 2017–2019, violations in the area of cleaning and disinfection consistently rank among the most frequent. Of 225 salons subjected to penalties, more than 80 were sanctioned specifically for noncompliance with sanitary standards; at the same time three categories of violations predominated: insufficient disinfection of instruments (33 cases), disregard for the protocol of daily cleaning and disinfection of pedicure/manicure tubs (32 cases), and reuse of single-use supplies (10 cases) [9-12]. The aggregation of these indicators points not to episodic failures, but to the systematic underperformance of the disinfection regimen requirements, especially with respect to water-containing facilities (see Fig. 2).

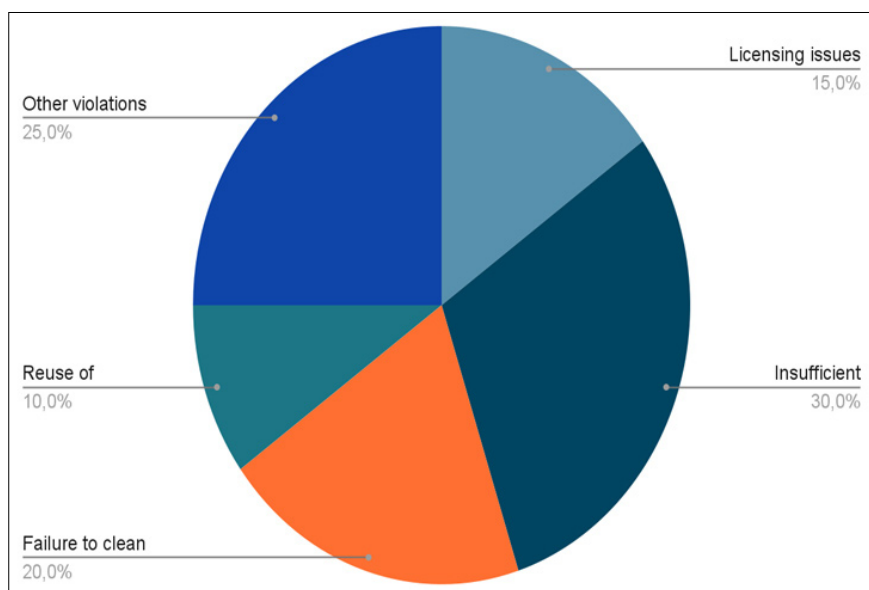


Fig. 2. Structure of recorded violations of sanitary and hygienic standards in nail salons (compiled by the author based on [9-12]).

The problem is exacerbated by a systemic resource deficit at supervisory authorities, which renders comprehensive oversight effectively unattainable. Thus, in Texas, for over 43 000 establishments in the beauty industry, including about 5 600 nail salons, only 29 inspectors are assigned [16]. Under such an imbalance, regular and in-depth inspections become organizationally impossible: a significant share of violations remains outside the field of view, and businesses continue to operate for months and even years with expired licenses or without licenses at all.

These data reveal a fundamental vulnerability of the current regulatory architecture. It presupposes unconditional and continuous adherence to complex disinfection protocols—a premise that, in real practice, does not withstand the test of the human factor, time constraints, and limited external oversight. From this follows a more reliable and rational risk-reduction trajectory: not to intensify compliance monitoring around an outdated technological procedure, but to replace it with a technology that initially minimizes hazards by eliminating the key source of risk—water. Such a shift moves the emphasis from behavior-dependent compliance, which is difficult to ensure, to built-in technological safety as an immanent property of the method.

Modern waterless, device-based approaches serve as an alternative to maceration practices. A telling illustration of this innovation paradigm is the proprietary E-File Dry Manicure technique in a combined implementation, developed and deployed by a leading master-instructor whose practice underpins the case study under consideration. The method completely excludes water contact with the client's hands; the cuticle and lateral nail folds are treated with a device (e-file) using specialized bits. The key to atraumatic performance is the Rounded Cone bit: in contrast to the Flame bit with a sharp tip commonly used in the United States, its rounded apex virtually reduces to zero the risk of cuts, overfiling of the nail plate, and excessive thinning of the cuticle. The device-based component is flexibly integrated with classical nipper excision, which makes it possible to finely tailor the procedure to the client's individual features (dry, moist,

elastic cuticle) and to achieve an impeccable result [13, 14].

Complete elimination of the aqueous environment removes a key reservoir for the proliferation and transmission of hydrophilic pathogens, including *P. aeruginosa* and the causative agents of onychomycoses. In doing so, the risk is shifted from the poorly reproducible and quality-heterogeneous disinfection of plastic tubs to the controlled sterilization of metal instruments. Sterilization regimens (for example, in a dry-heat oven) are more reproducible, standardized, and verifiable compared with surface treatment, which is critical for managing infection parameters [4].

Abandoning maceration preserves the structural integrity of the stratum corneum and the skin acid mantle, preventing a decline in barrier function. This reduces the likelihood of contact dermatitis and supports the natural anti-infective mechanisms, fully correlating with data on the harmful effects of hyperhydration of the skin [5, 15].

The use of a safety bit in combination with a localized, metered technique reduces the probability of iatrogenic damage to the epidermis; the latter, as is known, creates portals of entry for infection and increases tissue susceptibility to microbial colonization [3, 18].

The introduction of the technology in the United States, where it had previously been virtually absent, produced sustained client demand and made it possible to attain the position of the highest-paid specialist within the relevant niche in the state of Arizona. Packed auditoriums at educational sessions within leading industry expositions, particularly at America's Beauty Show in Chicago, demonstrate pronounced interest from the professional community in safe and highly effective approaches [17, 19]. The commercial outcome serves as a reliable marker of market viability: consumers and practitioners are willing to pay a premium for a service perceived as safer, more technologically advanced, and professionally validated. This refutes a possible thesis about the excessive complexity or high cost of waterless manicure for the mass segment, and the method itself is positioned as an emerging industry standard (see Fig. 3).

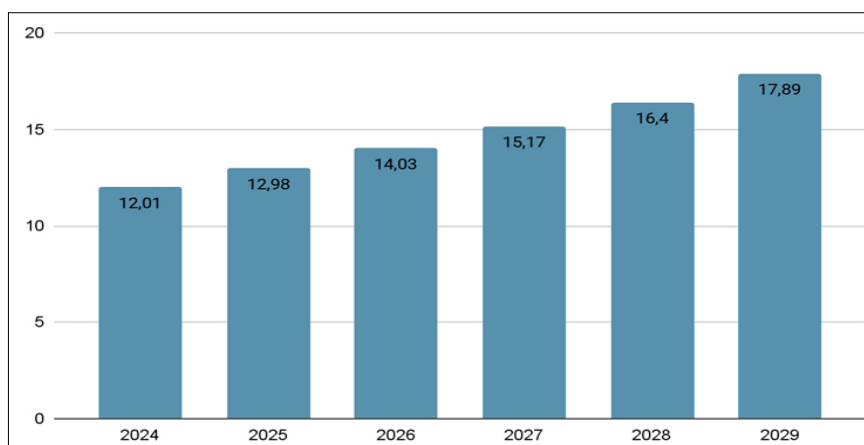


Fig. 3. Forecast of growth of the global nail salon services market (US\$ billion, 2024–2029) (compiled by the author based on [1]).

Beyond the direct therapeutic outcomes, the method demonstrates a pronounced socioeconomic effect. Specialists who have mastered the specified technology have been able to substantially increase the value of their services and expand their client base, which translated into an average income increase of 50–100%. This confirms that investments in innovative and safe solutions serve not only as a contribution to client well-being but also as a rational business strategy that ensures professional development and financial growth for practicing technicians.

CONCLUSION

The conducted study provided a holistic, interdisciplinary analysis of the risks inherent to traditional water-based maceration in nail services. The convergence of data from microbiology, dermatology, and regulatory practice analysis convincingly demonstrates that the specified method is associated with demonstrable and significant threats to client health. It has been shown that water in manicure bowls acts as a nutrient medium and a transport factor for opportunistic pathogens, primarily *Pseudomonas aeruginosa*, and also contributes to the formation of fungal infections. Simultaneously, maceration undermines the barrier properties of the skin: the integrity of the stratum corneum is disrupted and the acid mantle is neutralized, which increases the susceptibility of the skin to infectious agents and chemical irritants.

Enforcement analysis revealed the systemic insolvency of the current control model, which relies on adherence to disinfection protocols. The widespread nature of sanitary violations, combined with the limited resources of supervisory bodies, does not allow for a guaranteed level of safety when using water procedures.

Thus, the initial authorial hypothesis received full confirmation. A justified and logical step in the evolution of the industry is the abandonment of water maceration in favor of professional waterless hardware techniques. As shown by the case study analysis of the E-File Dry Manicure technique, the waterless format not only reduces risk but eliminates the very source of danger, shifting the emphasis from difficult-to-control disinfection to reliable, standardized sterilization of instruments. The set of advantages — microbiological and dermatological safety, atraumaticity, high quality, and aesthetic consistency — is confirmed both by professional recognition at the international level and by sustained consumer demand.

Based on the findings obtained, the following practical recommendations are formulated:

1. For practicing technicians and salon owners: Active mastery and implementation of waterless hardware manicure techniques is recommended. This will increase safety for clients and the specialists themselves, while simultaneously improving service quality — a key factor

in competitiveness, attracting a solvent audience, and revenue growth amid intensifying market competition.

2. For educational institutions and instructors: Training curricula for nail service specialists should be revised to include advanced modules in microbiology and dermatology to form a scientifically grounded understanding of risks. Training emphasis must shift from outdated standards based on maceration to the teaching of modern, safe, and in-demand hardware techniques.
3. For regulatory bodies and professional associations: It is necessary to initiate a review and updating of sanitary norms and rules in light of scientific data on the risks of water procedures. The sector's transition to safer technological standards should be encouraged through the development of appropriate guidelines, educational campaigns, and, if necessary, the introduction of differentiated requirements for salons employing waterless technologies.

Implementation of these recommendations will help enhance the overall level of safety and professional culture in the nail service industry, adequately responding to contemporary challenges and the public demand for high-quality, health-preserving services.

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