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Specific Features of Training in Safe Manicure and Thin Gel Coating: Comprehensive Analysis of Methodology, Biomechanics, And Dermatological Safety

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Abstract

The relevance of the study is determined by the rapid transformation of the global nail service market, where, against the background of growing demand for services, there is an increase in the incidence of iatrogenic onychodystrophies caused by aggressive treatment techniques and errors in the architecture of artificial coatings. The aim of the work is to provide a scientific rationale for and systematize the methodology of training in safe manicure that integrates medical standards of asepsis, the biomechanics of polymer materials, and the ergonomics of the technician's work. The study employed methods of systematic review of specialized literature, comparative analysis of hardware technologies, and examination of the physicochemical properties of modern gel systems. The results obtained demonstrate that the implementation of wet cuticle processing techniques and protocols for applying thixotropic gels in a thin layer (without leveling) significantly reduces the risks of thermal burns, contact dermatitis, and traumatic onycholysis. Key principles of instructional design for advanced training courses are formulated, based on psychomotor regularities in the acquisition of manual skills. The practical significance of the work lies in the creation of an evidence base for the standardization of next-generation educational programs. The information presented will be of interest to practicing manicure technicians, instructors, technologists of cosmetic brands, and managers of beauty salons oriented toward the premium segment and client safety.

In the end, it provides a collection of design patterns for the building of RTC services that can withstand active network threats and are less susceptible to abuse.

Keywords: safe manicure, training of technicians, thin gel coating, hardware manicure, onycholysis, nail biomechanics, wet processing, polymerization stress, dermatological safety, motor skills.

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1. Introduction

In the current configuration of the beauty and wellness industry, nail services occupy a special interdisciplinary position at the intersection of aesthetic cosmetology, clinical dermatology, and materials science. The rapid transformation of the market, driven by increasing consumer awareness and a significant tightening of regulatory and professional requirements regarding the safety of procedures, necessitates not a cosmetic update but a fundamental restructuring of the system of professional training for practitioners. According to forecast estimates, the nail services market will demonstrate stable growth: by 2029 its volume is expected to increase by 9.48 billion US dollars with a compound annual growth rate (CAGR) of 10.7 % [1].

Long-term forecasts indicate a potential achievement of a global market volume of 20.30 billion US dollars by 2030 [2]. However, behind these exponential economic indicators lies a qualitatively different structure of demand: the consumer of 2024–2025 is oriented not toward obtaining a merely decorative coating, but toward a comprehensive, clinically safe procedure integrated into a broader paradigm of health care and the practice of mindful self-care [4].

The scientific problem is formulated as a contradiction between the widespread use of traumatic cuticle treatment techniques (primarily deep hardware manicure formats) and the data accumulated in the medical community on the risk of irreversible damage to the matrix and nail bed. The relevance of the study is additionally confirmed by the increasing number of cases of acquired onycholysis and sensitization to methacrylates, which objectively requires the inclusion of strictly regulated biological and chemical safety protocols in educational programs.

The scientific novelty of the work lies in the theoretical and practical substantiation of the effectiveness of integrating the podological wet treatment method and the technology of thin reinforcement of nail plates into the structure of aesthetic manicure as a standardized approach to the prevention of occupationally induced and client pathologies.

The aim of the study is to develop a scientifically verified training model that minimizes the risks of mechanical traumatization and the toxic effects of chemical reagents while simultaneously ensuring high aesthetic characteristics and durability of the resulting outcome.

Within the framework of the **author's hypothesis**, it is assumed that abandoning the excessive volume of applied material (leveling procedures) and aggressive dry treatment in favor of thin rigid coatings and wet filing constitutes the only sustainable strategy for the development of the industry in the direction of prioritizing safety.

2. Materials and Methods

To achieve the stated objective and conduct a comprehensive analysis of the problem, an integrated methodological approach was employed, combining qualitative and quantitative research methods.

A targeted search and analytical processing of scientific publications were carried out in the databases Scopus, Web of Science, PubMed, and Google Scholar. The inclusion criteria comprised works devoted to the dermatology of the nail apparatus, polymer chemistry (especially acrylate systems), the assessment of the safety of hardware techniques, and issues of ergonomics in cosmetology. The selection of sources was conducted with regard to their methodological rigor and clinical relevance.

A comparison of the functional parameters of dry and wet hardware manicure was performed, including temperature regimes in the treatment area, the intensity and disperse composition of dust formation, as well as the nature of abrasive impact. Technical specifications from equipment manufacturers and the results of independent tests were used for the analysis, which made it possible to evaluate the technologies not only from the standpoint of subjective comfort but also from the perspective of objective biomechanical and hygienic indicators.

The empirical experience of implementing the author's safe manicure technique in the practice of a premium-segment salon was analyzed, where a sample of more than 30 practitioners who had undergone specialized training was formed. The dynamics of skill acquisition, the stability of the obtained results, and the frequency of complications arising under real conditions of a high-workload service were examined.

3. Results and Discussion

The analysis of the dynamics of key macroeconomic indicators shows that the nail service industry in developed and emerging economies is in a phase of stable expansion and qualitative transformation. In mature markets, primarily in the USA, the nail salon segment is integrated into the broader global nail care services market, whose total volume in 2024 is estimated at approximately 8.8 billion US dollars, with projected further growth rates in the medium term [3]. At the same time, the service itself is shifting from a simple cosmetic procedure to a format of comprehensive client well-being management: basic manicure and pedicure are complemented by relaxation rituals, elements of spa therapy, individual self-care consultations, and practices aimed at restoring emotional balance [6, 7].

From a substantive perspective, this reflects a broader

trend of wellness-ization in the sphere of everyday services: nail salons are beginning to function as spaces of short-term psychological refuge under conditions of increasing stress in the urban environment and digital overload. Within salons, the organization of the workspace, the interaction scenarios between technician and client, and the acoustic and lighting design are being rethought, while practices of sensory decompression are being implemented (aromatherapy, tactile techniques, gentle massage protocols for hands and wrists). Such changes make it possible to consider the nail service industry not only as part of the beauty sector, but also as a specific segment of the experience economy, where added value is formed through a complex emotional experience and the subjective feeling of care and acceptance, rather than solely through the final aesthetic result.

From the perspective of market structure and scale, the growth of the industry is based on a combination of several factors: the increase in household disposable income, changes in gender and age consumption patterns, and the strengthening of a normative attitude toward visible self-care as an element of social capital. In parallel, institutional diversification is observed: along with traditional salons, networks of franchised studios are developing, as well as premium mono-format establishments with a narrow specialization (for example, hardware manicure only or solely long-term coatings), and a broad segment of self-employed technicians working in co-working spaces and home environments. Such a multi-structural configuration complicates the statistical assessment of the industry, but at the same time increases its adaptability to demand shocks, as it allows client flows to be redistributed between formal and semi-formal service provision channels [9, 10].

At the global level, the nail service industry demonstrates signs of high resilience to cyclical demand fluctuations characteristic of traditional segments of the consumer market. Even under conditions of slowing economic growth and intensifying inflationary pressure, nail care services retain the status of relatively accessible luxury: a low average ticket and the possibility of targeted expense optimization make them less vulnerable compared to major durable purchases. The pandemic shock of 2020, which led to a sharp reduction in salon revenues due to lockdowns and sanitary restrictions, became in this sense a stress test for the industry: the decline in turnover was followed by accelerated recovery, and part of the demand migrated from the informal sector (home-based technicians) back to professional studios as consumer attention to hygiene, sterility, and compliance with safety regulations increased.

Finally, an essential macroeconomic effect of the development of the nail service industry is its contribution to employment and the formation of flexible forms of labor, primarily for women and migrants. The sector is characterized by a low entry threshold in terms of formal education, while simultaneously imposing high demands on specific manual skills, communicative competence, and client emotional management. The expansion of the salon network in cities of various sizes, the differentiation of price segments, and digitalization (online booking, service marketplaces, rating platforms) shape new trajectories of micro-entrepreneurship and self-employment. Taken together, this makes it possible to regard the nail service industry as a significant, albeit often underestimated, element of the contemporary service economy, where the processes of urbanization, feminization of labor, the growth of the care economy, and the institutionalization of everyday self-care practices intersect.

Below, Figure 1 presents the structure of consumer demand and the technological response of the industry.

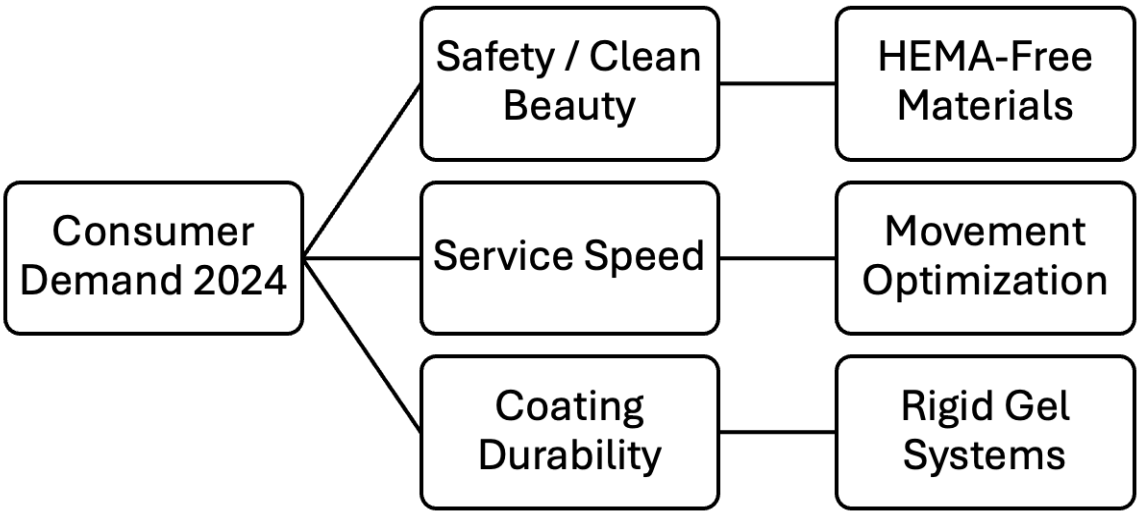

Fig. 1. The structure of consumer demand and the technological response of the industry (compiled by the author based on [1, 5, 8, 11]).

The growth of the market is inevitably accompanied by a more complex sanitary and hygienic profile of services: an increase in customer flow intensifies both infectious risks and cumulative chemical exposure. Analytical reviews record that the use of highly aggressive ingredients remains a significant unresolved problem [1].

In response, there is a growing demand for the greening of the product range, which is manifested in a shift of preferences toward products labeled HEMA-free [1].

Below, Table 1 presents a comparative analysis of market drivers and risks.

Table 1. Comparative analysis of market drivers and risks (compiled by the author based on [1, 3, 4, 12])

Market indicator	Statistics / Forecast	Interpretation for training
Market growth (USA)	$8.8 billion (2024) → $13.7 billion (2034)	Demand necessitates an increase in the number of qualified personnel.
Global growth	CAGR 10.7% until 2029	High competition will displace professionals with low qualifications.
Gel polish segment	Dominant market share	Training in working with gel is becoming a basic skill.
Trend	Demand for healthy services	Training methods should focus on preserving natural nails.

A fundamental engineering problem in the creation of an artificial coating for the nail plate lies in the substantial mismatch between the elastic modulus of keratin in the natural nail and that of the polymer materials used. The

natural nail exhibits pronounced flexibility and the capacity for elastic deformation in response to mechanical loading, whereas the polymer coating, particularly highly crosslinked gel and acrylate systems, displays considerably more rigid and static behavior. As a result, bending or twisting of the nail plate generates significant stresses at the nail–polymer interface, which over time may lead to microdamage of the adhesive layer.

A key factor determining both the safety and durability of the coating is polymerization shrinkage and the associated shrinkage stress. During curing of monomeric and oligomeric systems, the material volume decreases, which mechanically tightens the coating and transmits force to the underlying nail plate. Experimental data indicate a direct relationship between the thickness of the polymer layer and the magnitude of the force acting at the interface with the nail: the thicker the layer, the higher the resulting debonding stress, which increases the risk of the formation of detachments and onychodystrophic changes up to onycholysis (partial separation of the nail from the nail bed) [13, 16].

An additional complication is introduced by the heterogeneity of the mechanical characteristics of the nail itself. The natural nail plate is a multilayer keratin structure with varying fiber orientation and a moisture gradient through its thickness. This results in anisotropy of its elastic properties: in the longitudinal direction the nail is more resistant to bending, whereas the transverse and especially distal regions undergo greater deformation under everyday loads (pressing, impact, grasping objects). A rigid polymer layer applied to such a biological structure does not adapt to these micromovements, which enhances stress concentration in areas of pre-existing weakness of the nail (microtrauma, thinning, lamination).

From the standpoint of materials science, the magnitude of polymerization shrinkage is determined by the chemical nature of the monomers, the degree of crosslinking, and the curing kinetics. Rapid initiation and high-intensity irradiation during photopolymerization lead to the development of high shrinkage stresses over a short time interval, when the material has not yet had time to relax. In contrast, milder polymerization protocols (multistep or reduced intensity) allow partial redistribution of stresses due to viscoelastic flow of the forming network. However, in practical work there is often a tendency to minimize procedure time, which promotes the use of aggressive light-curing modes and thick material layers, thereby increasing the risk of pathological changes in the nail plate.

A clinically significant consequence of excessive shrinkage and interfacial stresses is not only onycholysis, but also a spectrum of subjective sensations reported by the client: a pronounced feeling of strong compression of the nails, pain on tapping or pressing, and increased discomfort in the first hours after polymerization. These symptoms reflect mechanical overstressing of the nail plate and the underlying tissues. In the presence of preexisting risk factors — a thinned nail plate, prior traumatic onychopathies, dermatological diseases (psoriasis, eczema, onychomycosis) — the additional load arising from polymerization shrinkage may accelerate the development of chronic damage and deformities. For this reason, optimization of coating thickness, the choice of more elastic systems, and the use of gentle polymerization regimens are regarded not only as aesthetic measures, but also as important preventive interventions.

Figure 2 below illustrates the change in shrinkage stress with increasing material thickness.

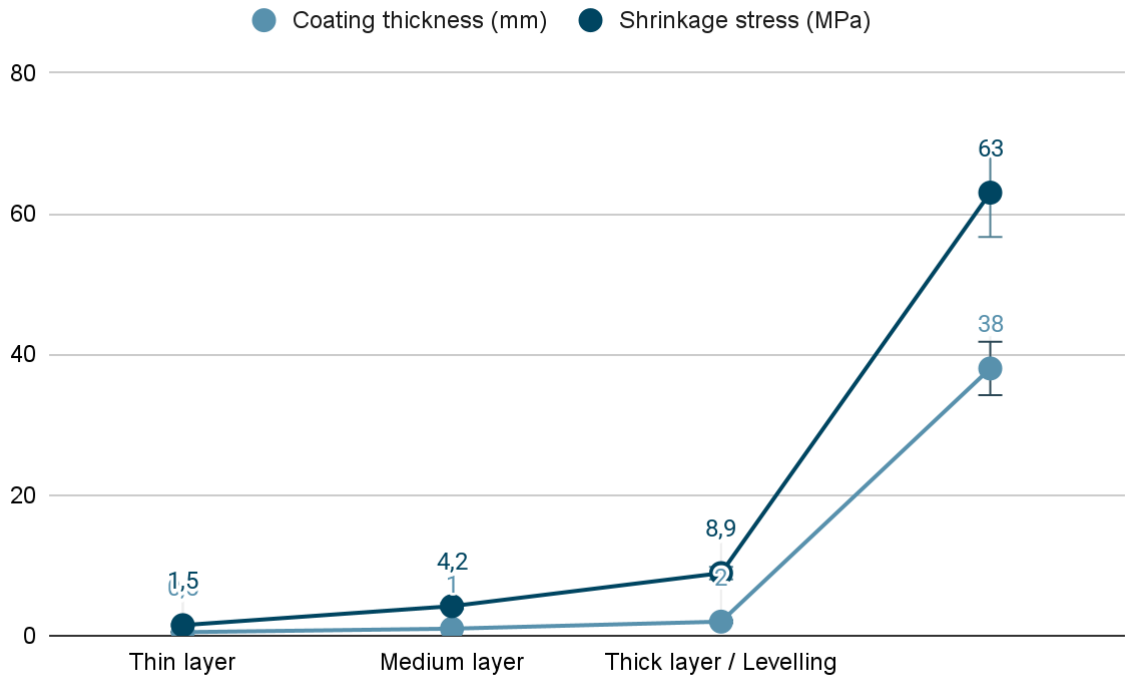

Fig. 2. Increase in shrinkage stress with increasing material thickness (compiled by the author based on [8]).

A thick leveling layer of a base or other polymer material, by virtue of its volume and the high rigidity of the system, forms substantially more pronounced polymerization and in-service stresses compared with a thin film. During curing, the material undergoes shrinkage, which is more pronounced the greater its thickness; the resulting stresses are concentrated in the nail plate–artificial material interface and in the areas of anatomical curvatures of the nail. This leads to local overloading of keratin structures and to the formation of microtears and delaminations, which clinically manifest as onycholysis, a sensation of tightness, pain on pressure, and increased sensitivity to temperature changes [14].

From the perspective of pedagogy and clinically justified practice, training of specialists should categorically exclude the normalization of techniques involving the application of thick base layers and, conversely, should emphasize layer-by-layer application of rigid materials with controlled thickness, taking into account their elastic modulus, degree of shrinkage, and adhesion characteristics [15, 18]. Within educational programs, this implies analysis of the biomechanics of the nail plate, modelling of stress distribution at different coating thicknesses, and the development of techniques in which each subsequent layer performs a clearly defined function (adhesive, leveling, architectural) but does not lead to excessive loading of the natural nail. Thus, the correct application technique is regarded not as an aesthetic tool but as a preventive and, in essence, therapeutic instrument.

Within the author's methodology, one of the key elements is the use of wet treatment in the format of spray technology borrowed from podology. In contrast to classical dry or aggressively instrument-based approaches, the spray method makes it possible to combine gentle softening of horny masses with minimal mechanical trauma to the periungual tissues and the distal edge of the nail plate. Fine-dispersion spraying of specialized solutions (keratolytic, antiseptic, emollient) ensures uniform hydration and controlled action on the cuticle and hyponychium, reducing the risk of microcracks, hangnails, and subsequent inflammatory reactions.

An additional advantage of spray technology lies in its ability to form an optimally prepared, moderately hydrated, and cleansed substrate for the subsequent application of rigid materials. Such preliminary treatment reduces the number of keratinized and unstable fragments that may become a weak link in the adhesion layer and, consequently, decreases the likelihood of detachments and onycholysis under polymerization stress. Incorporation of wet treatment into a standardized manicure protocol makes it possible to regard the entire process not as a purely cosmetic service but as a structured intervention aimed at preserving the integrity of the nail plate, preventing chronic trauma, and enhancing the biomechanical compatibility of the natural nail with artificial coatings.

The comparative effectiveness of dry and wet treatment is demonstrated below in Fig. 3.

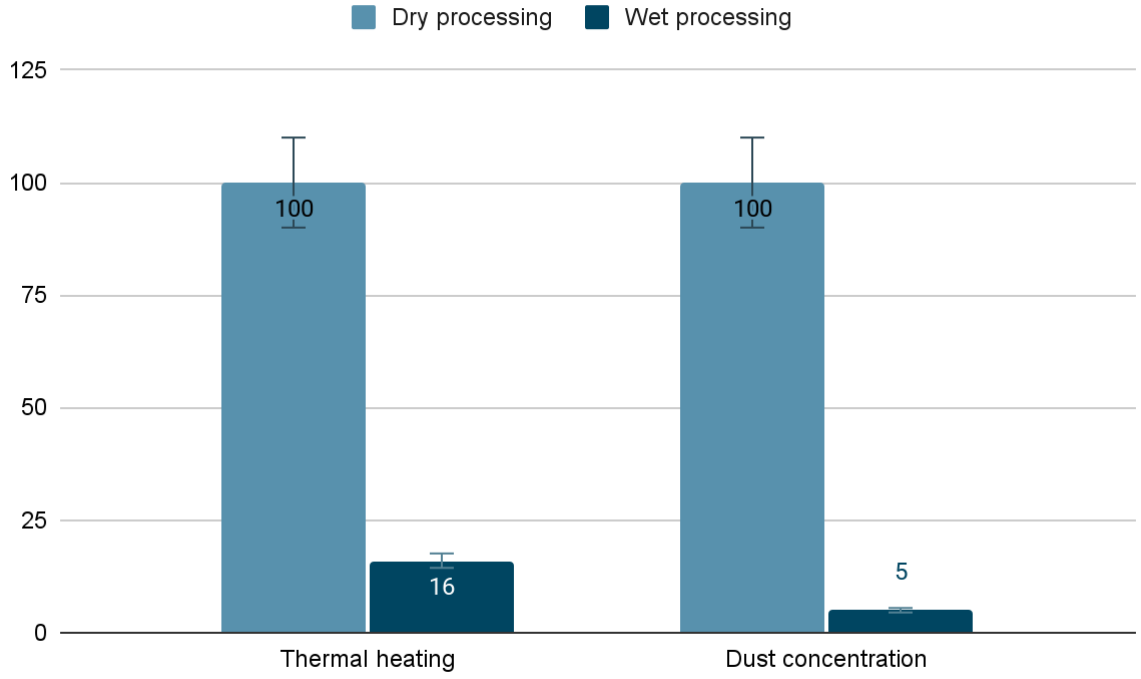

Fig. 3. Comparative effectiveness of dry and wet treatment (compiled by the author based on [17]).

Water cools the treatment area, preventing burns of the pulp and matrix even when working at high rotational speeds [19]. The wet technique binds 91–95% of fine dust particles at the moment of their formation, protecting the technician's lungs from occupational diseases (asthma, allergoses) [20]. The safety of the procedure is 80% determined by the geometry of the bur. A strict protocol for abrasive selection is used in training.

Table 2 below presents the classification of burs in the author's methodology of safe manicure.

Table 2. Classification of bits in the author's safe manicure technique (compiled by the author based on [21]).

Bit type	Geometry / Abrasive	Purpose	Safety note
Diamond ball	Sphere, red/blue notch	Cuticle (eponychium) removal	Strictly No Nail Contact: Work only on the skin. Contact with the nail causes grooves.
Onyclean	Polygonal, without abrasive	Pterygium removal	Atraumatic. Ideal for diabetics and thin skin. Does not file the nail.
Safety Bit	Carbide, rounded top	Material removal	The smooth end prevents cuts of the cuticle during coating removal.
Flame	Pointed	Lifting the cuticle (for professionals)	High risk of overfiling with the tip. Requires an exact 45° angle.

The proprietary technique is based on the use of wet polishing with a diamond ball bur, in which the stratum corneum in the area of the periungual fold and cuticle is removed in a stepwise manner under continuous control through visual and tactile feedback. Water or a specialized spray acts as a lubricating and cooling medium, reducing friction, local overheating, and dust formation. As a result, excessive keratinization can be gently reduced without tissue maceration and without the formation of irregular frayed edges characteristic of aggressive excisional or dry hardware manicure, which substantially decreases the risk of microcracks and subsequent inflammation.

The training methodology for this technique is grounded in Fitts's law (Fitts's Law), which describes the regularity whereby the higher the required accuracy of hitting a target, the more time is needed to execute the movement. In this context, the cuticle zone is regarded as a high-precision working area with a minimal permissible error margin. Attempts to artificially accelerate the work of a novice practitioner without established fine motor skills lead to a sharp increase in the number of errors, including deep cuts, violations of epithelial integrity, and trauma to the matrix. Thus, the speed of actions should be the result of automation and a consolidated motor skill, rather than an externally imposed requirement for work pace.

From the standpoint of neurophysiology and motor learning theory, the acquisition of wet polishing with a diamond ball bur can be considered as a stepwise transition from the cognitive stage (when the performer consciously controls each movement) to the associative and subsequently autonomous stage. At the early stage, priority is given to slow, controlled movements, work with elbow and wrist support, and limitation of the amplitude and angle of attack of the bur relative to the nail plate. Repetition of standard trajectories (linear, arcuate) and consolidation of uniform pressure parameters and rotational speeds form a stable sensorimotor map in the cerebral cortex, which reduces movement variability and the risk of injury as practical experience accumulates.

From a practical standpoint, the integration of Fitts' law into the educational protocol makes it possible to justify a stepwise increase in complexity: first, movements are practiced on models with minimal risk (mannequins, tips, then clients without marked hyperkeratosis), and subsequently the time allotted for performing manipulations is gradually reduced while maintaining the same safety criteria. The mandatory inclusion of modules on ergonomics (position of the practitioner's and client's body, finger fixation, selection of the diameter and abrasiveness of the diamond ball bur, optimal rotational speed of the device) and on the biomechanics of instrument grip additionally reduces the load on the practitioner's musculoskeletal system and increases the reproducibility of the result. Taken

together, this forms not only a more predictable aesthetic outcome, but also a stable standard of atraumatic work with periungual tissues.

The author's training program, tested on more than 30 students in the USA and European countries, is focused predominantly on the development of biomechanically optimized hand positioning with an emphasis on little-finger support. This hand configuration is regarded as a key element of the kinematic chain shoulder–forearm–hand–instrument and makes it possible to significantly reduce tremor, provide metered, strictly controlled pressure on the working surface, and minimize extraneous movements. This, in turn, is critically important when working in anatomically and functionally hazardous areas, in the region of the nail sinuses and matrix, where any excessive mechanical impact is fraught with injury to the nail germinal zone and the formation of persistent dystrophic changes.

A separate module of the program is devoted to the management of clients with diabetes mellitus, angiopathies, and marked cutaneous hyperesthesia. For this group of patients, the wet technique is considered the gold standard, since the combination of tissue hydration and a reduced coefficient of friction between the bur and the skin makes it possible to practically eliminate microcuts and overheating of the treated area, thereby reducing the risk of local infection, exacerbation of diabetic foot/hand syndrome, and subsequent trophic complications[15]. The use of burs of the Onyclean type with an atraumatic geometry of the cutting part and controlled abrasiveness makes it possible to perform grinding and reduction of keratinized masses without disrupting the integrity of the epidermal barrier, preserving the protective function of the skin and reducing the likelihood of a postprocedural inflammatory reaction.

In addition, within the framework of the program, emphasis is placed on a risk-oriented approach to procedures: trainees master algorithms for preliminary screening (assessment of the condition of the skin, peripheral circulation, and sensitivity, including the use of simple tests for superficial and deep sensitivity), as well as documentation of the initial status (photographic documentation, structured description). The principles of interdisciplinary interaction with endocrinologists and surgeons are practiced for the detection of signs of complicated diabetes, along with criteria for the immediate discontinuation of the procedure and referral of the patient to a physician. Thus, the program integrates instrument biomechanics, clinically oriented risk assessment, and atraumatic tissue processing technologies into a single system, which increases both safety and reproducibility of the result.

4. Conclusion

The conducted study convincingly demonstrates that the contemporary system for training manicure professionals should rely not on empirical so-called school traditions, but on strict scientific foundations that include elements of evidence-based medicine, ergonomics, and materials science. The transition from dry processing techniques to wet hardware manicure is considered not as a fashionable trend, but as a natural technological shift: when the work process is properly organized, it makes it possible to reduce the dust load on the workspace and on the respiratory tract of the professional and the client by up to 95%, while simultaneously minimizing the risk of thermal tissue damage due to more efficient heat dissipation and a reduced coefficient of friction between the bit and the substrate. In this way, the technology directly influences both the safety of the procedure and the preservation of the professional longevity of the specialist.

From the standpoint of materials science, it has been demonstrated that abandoning the habitual practice of leveling the nail plate with thick layers of elastic base products in favor of using thin, rigid, thixotropic gels leads to a substantial reduction in the load on the nail plate and surrounding tissues. A thin-layer coating decreases the risk of onycholysis associated both with an excessive mechanical lever during material lifting and with chronic pressure on the nail bed, and also reduces the likelihood of chemical burns due to a lower exothermic peak during polymerization. Additionally, this approach promotes a more predictable wear of the coating and facilitates its subsequent correction, which reduces the cumulative trauma to the nail over long-term wearing cycles.

The pedagogical component of the methodology is oriented toward a rethinking of priorities: training is aimed not at developing high procedure speed at the early stages, but at practicing movement accuracy, biomechanically sound positioning of the hand and fingers, as well as stable control of pressure and the instrument vector. Within the framework of the three-stage model of skill formation, it is precisely the focus on qualitative parameters in the consciously controlled phase that leads to the skill acquiring high speed in the

autonomous stage without loss of quality and safety. In this way, the typical pedagogical error of traditional courses is eliminated, whereby the race for speed forms stable incorrect motor patterns that are subsequently extremely difficult to retrain.

The presented methodology, integrating technological, materials science, and pedagogical principles, has already been implemented in the practice of a number of salons in the USA and Europe and demonstrates high clinical and commercial effectiveness. On the one hand, an increase is observed in the loyalty and satisfaction of clients oriented toward premium service, prevention of damage, and long-term preservation of the health of nails and skin. On the other hand, a decrease is recorded in the number of complaints of discomfort, burning, post-procedural pain, and coating damage, which confirms the high demand for this approach and its compliance with the current trend toward health-oriented rather than purely aesthetically oriented beauty services. Additionally, salons that implement such standards obtain a competitive advantage on the market, as they can position their services as based on scientifically grounded protocols rather than solely on the subjective experience of the professional.

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