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Anatomy and Physiology of the Nail Apparatus in the Context of Aesthetic Manicure

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Abstract
The nail apparatus is a complex cutaneous appendage comprising the nail plate, nail matrix, nail bed, proximal and lateral folds, cuticle (eponychium), and hyponychium. Its physiological role extends beyond aesthetics: the nail is involved in protecting the fingertip, enabling precise manipulation, and sensory function. Of particular importance for aesthetic manicure are the barrier structures (cuticle/proximal fold and hyponychium), as well as the properties of the nail plate as a " keratin barrier" with a low lipid content and limited permeability. This article systematizes the anatomical and physiological features of the nail apparatus and discusses practical implications for the safe performance of aesthetic manicures.

Keywords: Nail apparatus, matrix, cuticle, hyponychium, nail plate, nail growth, barrier, manicure.

Introduction

The scientific novelty of this article lies in its applied interpretation of the anatomy and physiology of the nail apparatus in the context of aesthetic manicure, with an emphasis on the barrier and growth structures of the nail. The work systematizes anatomical and physiological "risk points" and substantiates practical conclusions for gentle manicure techniques, linking fundamental dermatological knowledge with the prevention of cosmetically induced nail lesions.

The nail apparatus is the largest and anatomically complex skin appendage located on the dorsal surface of the distal phalanges of the fingers and toes. It serves not only aesthetic but also important protective and sensory functions, providing support for the fingertip, assisting in fine manipulation, and mechanically protecting the distal phalanges. The nail apparatus includes the nail plate, nail matrix, nail bed, proximal and lateral nail folds, and barrier structures of the transition zones (cuticle/ eponychium and hyponychium), which determine the nail area's resistance to physical and microbial influences.

In the context of aesthetic manicure, it is critical to understand that the nail plate is a product of the matrix, and its normal growth and appearance depend on the functional integrity of all elements of the nail unit. A review of nail biology emphasizes the interrelationships between the matrix, folds, and bed, and indicates that interventions that disrupt their integration can lead to permanent morphological changes in the nail [1].

In parallel, the review " formidable nail barrier " shows that the nail plate has special barrier properties (microstructure, composition and low permeability for a number of substances), which determines both the possibilities and limitations of external influences (polishing, dehydration, contact with solvents/coatings) and explains why in clinical practice it is not so much the "nail itself" that is affected, but the soft tissues surrounding it [2].

Modern aesthetic manicure techniques (cut and hardware manicure, combined techniques, surface buffing, and application of durable coatings) involve regular manipulation of the cuticle and nail folds, as well as the superficial layers of the nail plate. A dermatological review of cosmetically induced nail lesions emphasizes that some complications are associated with trauma to barrier structures (especially the proximal fold and cuticle) and the effects of materials/procedures (instruments, filing, coatings) on the nail unit [3].

Thus, consideration of the anatomy and physiology of the nail apparatus in the applied plane of aesthetic manicure allows us to substantiate gentle processing techniques, identify “anatomical risk zones” and reduce the likelihood of inflammatory and dystrophic complications associated with dysfunction of the matrix and barrier structures of the nail unit.

The nail apparatus is a specialized cutaneous appendage whose anatomical integrity determines the normal growth, shape, and resistance of the nail to external influences. It consists of the nail plate, nail matrix, nail bed, proximal and lateral nail folds, cuticle (eponychium), and hyponychium. Each of these structures performs a strictly defined function, which is of fundamental importance in the context of aesthetic manicure.

The nail matrix is the primary growth zone and is responsible for nail plate formation. Matrix keratinocytes actively proliferate and undergo keratinization, forming the dense keratin structure of the nail. Even minimal damage to the matrix can lead to persistent nail plate dystrophies (grooves, splitting, and deformations), as demonstrated by clinical and morphological studies of the nail apparatus [4].

The nail plate consists of densely packed keratin layers and performs a mechanical protective function. Unlike the stratum corneum, it contains minimal lipids and is characterized by low elasticity, while its mechanical properties are significantly dependent on water content. These characteristics make the plate susceptible to excessive stress. filing and dehydration during manicure [5].

The nail bed provides fixation and sliding of the nail plate along the distal phalanx. The functional interaction of the bed and plate is important for maintaining normal adhesion; disruption of this connection can lead to onycholysis, especially with traumatic and chemical exposures [6].

The proximal nail fold and cuticle (eponychium) form a key barrier element of the nail apparatus. The cuticle is the keratinized edge of the proximal fold that "seals" the nail pocket, preventing the penetration of water, microorganisms, and chemicals into the matrix area. Modern dermatological reviews emphasize that aggressive cuticle removal disrupts this barrier and increases the risk of inflammatory complications [7].

The hyponychium, a specialized epithelial zone beneath the free edge of the nail, serves an additional protective function, sealing the subungual space. Damage to this zone can contribute to infection and disruption of the distal nail attachment [4].

Thus, the anatomy of the nail apparatus is a functionally interconnected system, where trauma to one structure can affect the condition of the entire nail unit, which must be taken into account when performing an aesthetic manicure.

Table 1 - The main structures of the nail apparatus and their functions

Structure	Anatomical characteristics	Main function	Practical importance for manicure
Matrix	Proximal growth zone under the nail fold	Formation of the nail plate	Trauma leads to permanent nail deformities
Nail plate	Dense keratin structure	Mechanical protection, support	Excessive filing reduces strength and elasticity
Nail bed	Epithelium under the plate	Nail fixation and sliding	Damage contributes to onycholysis
Proximal fold and cuticle	Transition of the skin into the nail apparatus	Barrier protection of the matrix	Aggressive removal breaks the barrier
Hyponychium	Distal barrier zone	Protection of the subungual space	Trauma increases the risk of infection

The physiological characteristics of the nail system determine its response to the mechanical, chemical, and physical influences typical of aesthetic manicures. Key factors include nail growth, keratinization , water exchange, and the barrier properties of the nail plate and periungual tissues. Nail growth occurs through the proliferation of matrix keratinocytes and normally averages 2.5–3.5 mm per month for fingernails. Growth rate depends on age, blood supply, hormonal levels, and the presence of trauma. Physiologically, any damage to the matrix delays the development of the nail plate, which explains the delayed appearance of grooves and deformities after traumatic manicure procedures [6].

Keratinization of the nail plate differs from keratinization of the epidermis. The nail is composed of hard keratin with a dense filament structure and minimal lipid content, which provides high mechanical strength but reduces elasticity. These characteristics make the nail plate susceptible to excessive thinning during filing and polishing [5].

Water balance and hydration play a key role in the mechanical properties of the nail. Water acts as the primary "plasticizer" of the nail plate: with increased hydration, the nail becomes more flexible, while with dehydration, it becomes brittle. Experimental studies have shown that repeated "wetting-drying" cycles significantly alter the strength and stability of the nail, which is of practical importance for frequent manicures and exposure to solvents [8].

The barrier properties of the nail plate are characterized by low permeability to most substances compared to the skin. However, periungual structures (proximal fold, cuticle, hyponychium) remain the primary penetration pathway for chemical agents. This explains why, during aesthetic manicures, it is not so much the nail plate itself that is physiologically more vulnerable, but the surrounding soft tissues [7].

Taken together, the physiology of the nail determines the need for gentle manicure techniques aimed at preserving the matrix, optimal hydration, and barrier function of the periungual structures.

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Table 2 - Physiological processes of the nail and their importance for aesthetic manicure

Physiological aspect	Characteristic	Practical importance for manicure
Nail growth	Dependent on matrix activity; 2.5–3.5 mm/ month	Matrix injuries cause delayed deformities
Keratinization	Hard keratin, low lipid content	Excessive filing reduces the strength of the nail.
Hydration	Water is the main plasticizer of the nail	Frequent dehydration → fragility
Barrier function	Low plate permeability	The main risk is damage to the cuticle and folds
Adaptation to the load	Slow restoration of structure	Intervals between aggressive procedures are necessary

From an anatomy and physiology perspective, aesthetic manicures affect structures with varying degrees of vulnerability. The greatest risk of complications is associated not with the nail plate itself, but with the barrier and growth zones, damage to which can lead to inflammatory, degenerative, and infectious changes.

The proximal nail fold and cuticle (eponychium) form a physiological "seal" of the nail pocket, preventing the penetration of water, microorganisms, and chemicals into the matrix. Dermatological reviews emphasize that aggressive trimming or excessively pushing back the cuticle disrupts this barrier and increases the risk of acute and chronic paronychia, as well as secondary infections [3]. In aesthetic manicures, this area is considered one of the most vulnerable.

The matrix is the primary growth zone of the nail, and any traumatic impacts to its projection (pressure from instruments, rough instrumentation of the proximal zone) can cause persistent defects in the nail plate. Clinical observations show that damage to the matrix manifests as grooves, thinning, or deformation of the nail weeks and months after the procedure [4].

Although the nail plate has high mechanical strength, its physiological properties depend on its thickness and hydration level. Excessive filing and grinding lead to thinning of the plate and disruption of its water balance, making the nail more brittle and sensitive to hydration-dehydration cycles [5]. At the same time, the plate itself is less vulnerable to chemical penetration than the periungual skin.

Lateral folds are often subject to mechanical trauma during nail shaping. Damage to these folds promotes inflammation and serves as an entry point for microorganisms, especially when combined with maceration and disruption of the skin's barrier function [3].

The hyponychium serves a protective function at the distal edge of the nail, sealing the subungual space. Trauma to this area (deep cleaning "under the nail," excessive shortening of the free edge) can lead to pain, inflammation, and an increased risk of infection [4].

Thus, the anatomical and physiological "risk points" of aesthetic manicure are primarily associated with the zones that provide growth and barrier protection for the nail, which justifies the need for gentle techniques and the minimization of traumatic effects.

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Table 3 - Anatomical and physiological "risk points" in aesthetic manicure

Structure of the nail apparatus	Physiological role	Potential risks during manicure	Possible consequences
Proximal fold and cuticle	Barrier, matrix protection	Circumcision, aggressive pushing away	Paronychia, infections
Matrix	Nail plate growth	Pressure, trauma in the proximal zone	Persistent nail deformities
Nail plate	Mechanical protection	Excessive filing, dehydration	Brittleness, thinning
Lateral ridges	Lateral nail protection	Trauma during formation	Inflammation, pain
Hyponychium	Sealing of the subungual space	Deep cleaning, trauma	Pain, risk of infection

The anatomical structures of the nail apparatus form a functionally unified system, in which each zone plays a specific role in nail growth, mechanical protection, and barrier function. For aesthetic manicure, it is crucial to consider that trauma to individual elements (primarily the matrix, proximal nail fold, and hyponychium) can lead to clinically significant damage, while gentle treatments preserve the physiology of the nail unit. A systematization of anatomical structures and corresponding practical conclusions is presented in Table 4, facilitating the translation of anatomical and physiological knowledge into applied nail practice.

Table 4 - Structures of the nail apparatus and practical conclusions for manicure

Structure of the nail apparatus	Anatomical and physiological function	Practical conclusions for manicure	Possible consequences of violation
Matrix	Growth and formation of the nail plate	Eliminate pressure and trauma in the projection of the proximal ridge	Persistent dystrophies, grooves, deformations
Nail plate	Mechanical protection, support	Avoid excessive filing and thinning	Brittleness, delamination, increased sensitivity
Nail bed	Fixation and sliding of the plate	Minimize trauma and chemical exposure	Onycholysis
Proximal fold and cuticle	Barrier protection of the matrix	Gentle cuticle relief, avoiding aggressive trimming	Paronychia, inflammation, infection
Lateral nail folds	Lateral stabilization of the nail	Gentle processing without microtrauma	Pain, swelling, inflammation
Hyponychium	Sealing of the subungual space	Avoid deep cleaning under the nail	Pain, infectious complications

Therefore, in the context of aesthetic manicure, two ideas are key: the cuticle/proximal fold and hyponychium are functional barrier elements, not “excess tissues”; the nail plate is water-dependent The keratin barrier is sensitive to thinning and hydration-dehydration cycles. Practical manicure safety is determined by gentle techniques, minimizing trauma, and respect for the barrier anatomy of the nail apparatus, which is consistent with dermatological reviews of cosmetically induced nail diseases.

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