

Nutritional Biologics for Skin and Hair



Sunder Gidumal, MD^a, Francis Reyes Orozco, MD^a, Gabrielle Cahill, MD^b, Riley Rearden^c, Jay Williams, PhD^{c,*}

KEYWORDS

• Hair • Nutrition • Skin • Facial plastic surgery • Face

KEY POINTS

- Screen aesthetic surgery patients for nutritional deficiencies that may impair wound healing, hair growth, and skin quality.
- Recommend a Mediterranean-style, low-glycemic diet to reduce inflammation, oxidative stress, and glycation-related skin aging.
- Consider targeted supplementation (e.g., collagen peptides, omega-3 fatty acids, probiotics, zinc, and vitamin D) when clinically indicated.
- Incorporate gut health, sleep quality, and circadian rhythm optimization into comprehensive skin and hair wellness counseling.
- Nutritional interventions should complement—not replace—evidence-based medical and surgical treatments.

INTRODUCTION

Skin and hair are dynamic biological systems that respond acutely to nutritional status, hormonal milieu and environmental stressors. Understanding the interplay between diet and dermatologic physiology is increasingly important in aesthetic medicine because optimal skin and hair quality underpins the success of surgical and regenerative procedures. The integumentary system is both a barrier and a sensory organ; it requires a complex supply of macro- and micronutrients to maintain cell turnover, lipid composition, barrier function and extracellular matrix integrity. Modern life exposes individuals to ultraviolet (UV) radiation, pollutants and psychological stress that accelerate production of reactive oxygen species (ROS), matrix metalloproteinases (MMPs) and inflammatory cytokines. Nutritional deficiencies or unbalanced diets compromise the skin's ability to neutralize these insults, resulting in increased oxidative stress, glycation of structural

proteins, impaired barrier function and telogen effluvium. Consequently, nutritional assessment has become an integral part of preoperative planning, postprocedural recovery and long-term maintenance of aesthetic outcomes.

This article provides a comprehensive overview of the evidence linking nutrients and bioactive compounds with skin and hair health. It reviews mechanistic pathways by which nutrients influence keratinocytes, fibroblasts, sebaceous glands, melanocytes and hair follicles. Micronutrients such as vitamins A, C, D, E, and the B complex regulate keratinocyte differentiation, collagen synthesis, wound healing and immune function.^{1–3} Trace minerals like zinc and selenium act as essential cofactors in antioxidant enzymes and transcription factors.^{1,4} Proteins supply amino acids for keratin, collagen and elastin, while fats provide essential fatty acids for barrier lipids and modulate inflammatory pathways. We also examine nutraceuticals, including carotenoids

^a Department of Otolaryngology - Head and Neck Surgery, UCLA, Los Angeles, CA, USA; ^b Department of Otolaryngology-Head & Neck Surgery, UCLA, USA; ^c Lifestyle Medicine, Dr Gregory S. Keller, Santa Barbara, USA

* Corresponding author. 8 Richland Place, Pasadena, CA 91103.

E-mail address: jay@jaywilliamsphd.com

Abbreviations

AGE	advanced glycation end products
EGCG	epigallocatechin gallate
MMP	matrix metalloproteinases
NF-κB	nuclear factor-kappa B
ROS	reactive oxygen species
UV	Ultraviolet

like astaxanthin and lycopene, polyphenols such as curcumin and cocoa flavanols, probiotics that modulate the gut–skin axis, glycation inhibitors and melatonin, and analyze their roles in photoprotection, antiaging and disease management.^{1,5–8} Finally, we discuss dietary patterns, supplementation strategies and future directions for clinicians integrating nutritional biologics into facial plastic surgery and regenerative practice.^{9,10}

MECHANISTIC PATHWAYS OF NUTRITION AND SKIN AGING

Skin aging results from a complex interplay of intrinsic and extrinsic factors. Intrinsic aging is a genetically programmed process characterized by gradual decline in fibroblast proliferation, reduced synthesis of collagen and hyaluronic acid, and increased fragmentation of elastic fibers. Extrinsic aging is largely driven by UV radiation, visible light, infrared exposure, pollution, smoking and poor nutrition. Exposure to UVB and UVA initiates photo-oxidative stress by generating ROS in keratinocytes and fibroblasts. ROS activate transcription factors such as activator protein-1 and nuclear factor-kappa B (NF-κB), leading to increased expression of MMPs that degrade collagen types I and III and elastin, while decreasing tissue inhibitors of metalloproteinases. Simultaneously, UV and environmental pollutants induce inflammatory cytokines (interleukin-1beta, interleukin-6, TNF-alpha), cyclooxygenase-2, and inducible nitric oxide synthase, promoting vasodilation, edema and erythema.¹ These processes disrupt the epidermal barrier, compromise DNA repair capacity and accelerate wrinkle formation.

Advanced glycation end products (AGEs) further compromise dermal integrity. Glycation is a nonenzymatic reaction between reducing sugars and protein amino groups that forms Schiff bases and Amadori products; subsequent oxidation yields AGEs that cross link collagen and elastin, reduce skin elasticity and induce yellow discoloration.¹¹ AGEs interact with the receptor for AGEs on keratinocytes and endothelial cells, triggering oxidative stress and NF-κB mediated inflammation. High dietary sugar intake and smoking accelerate AGE formation, while caloric

restriction and certain phytochemicals exert anti-glycation effects.¹¹

The gut-skin axis is another key pathway: dysbiosis of intestinal microbiota increases intestinal permeability (leaky gut) allowing lipopolysaccharide translocation and systemic inflammation that can exacerbate acne, rosacea and eczema. Probiotics and prebiotics modulate the gut microbiome to reduce systemic inflammation and improve skin barrier function.^{12,13} Understanding these pathways sets the stage for targeted nutritional interventions that support collagen synthesis, reduce oxidative stress, modulate inflammation and maintain the microbiome.

VITAMINS

Vitamin a (Retinoids and Carotenoids)

Vitamin A includes retinol, retinaldehyde, retinoic acid and provitamin A carotenoids such as beta-carotene and alpha-carotene. Retinoic acid binds nuclear receptors to regulate gene transcription involved in keratinocyte differentiation, sebaceous gland function, and hair follicle morphogenesis. Adequate retinoid status maintains epidermal turnover and prevents hyperkeratosis; deficiency causes follicular hyperkeratosis, xerosis, hair loss and impaired wound healing.³ Excess retinoid intake can lead to alopecia, cheilitis and hepatic dysfunction; balanced intake is thus crucial. Topically applied retinoids are well-established treatments for photoaging, acne and psoriasis; oral isotretinoin is effective for severe nodular acne and papulopustular rosacea.¹⁴ Dietary sources include liver, fish oil, eggs and yellow-orange vegetables. Carotenoids such as beta-carotene and lycopene accumulate in the epidermis and provide photoprotection by quenching singlet oxygen and scavenging free radicals.

Vitamin C (Ascorbic Acid)

Ascorbic acid is a water-soluble antioxidant and an essential cofactor for hydroxylases involved in collagen stabilization. Normal skin contains high concentrations of vitamin C; it enhances collagen synthesis, modulates gene expression in fibroblasts, and protects against UV-induced photodamage.² Deficiency results in scurvy with manifestations such as skin fragility, perifollicular hemorrhage, corkscrew hairs and impaired wound healing.² Because the epidermis is avascular, delivery of vitamin C occurs by diffusion from the dermis; adequate dietary intake is essential. Food sources include citrus fruits, berries, tomatoes, bell peppers and leafy greens. Oral supplementation may augment dermal vitamin C and has been shown to improve facial

wrinkling and elasticity in combination with collagen peptides.¹⁵

Vitamin D

Vitamin D3 is synthesized in the skin upon UVB exposure and is hydroxylated in the liver and kidney to the hormonally active calcitriol. Keratinocytes express vitamin D receptors; vitamin D regulates epidermal proliferation and differentiation, enhances barrier function by increasing cathelicidin and defensin antimicrobial peptides and modulates immune responses. Low vitamin D levels are associated with atopic dermatitis, psoriasis and alopecia areata; supplementation may be beneficial in individuals with limited sun exposure or darker skin phototypes.⁹

Vitamin E

Vitamin E is a lipid-soluble antioxidant that protects cell membranes from lipid peroxidation. The most abundant form in human skin is alpha-tocopherol; it acts synergistically with vitamin C to regenerate oxidized tocopherols and reduces UV-induced erythema and edema. Oral supplementation improves photoprotection but high doses are associated with adverse events; topical application with vitamin C and ferulic acid reduces UV-induced erythema.¹

B-Complex Vitamins

Niacinamide (vitamin B3) enhances epidermal differentiation, increases ceramide and free fatty acid synthesis and reduces transepidermal water loss. It downregulates inflammatory cytokines and inhibits melanosome transfer, making it useful for hyperpigmentation and rosacea. Biotin (vitamin B7) is required for keratin production; deficiency leads to alopecia and dermatitis. Folic acid and vitamin B12 are required for DNA synthesis; their deficiencies can present as hyperpigmented macules, hair loss, and glossitis. Pantothenic acid supports coenzyme A production and has been used to treat acne. Adequate intake of B-complex vitamins through a balanced diet supports healthy skin and hair.¹

MINERALS AND TRACE ELEMENTS

Zinc

Zinc is the third most abundant trace element in skin and acts as a cofactor for over 300 enzymes and thousands of transcription factors. It plays critical roles in DNA repair, keratinocyte proliferation, immune function and collagen synthesis.⁴ Zinc deficiency manifests as alopecia, periorificial dermatitis, delayed wound healing and increased

susceptibility to infections. Oral zinc supplementation has demonstrated benefits in acne and wound healing; however, large doses can cause gastrointestinal upset and interfere with copper absorption. In rosacea, oral zinc sulfate trials show mixed results, while topical zinc sulfate solution has shown moderate responses.¹⁴

Copper

Copper is a cofactor for lysyl oxidase, which catalyzes cross linking of collagen and elastin. It participates in melanin synthesis, contributes to wound healing and has antimicrobial properties. Copper peptides stimulate collagen synthesis, increase angiogenesis and act as antioxidants; topical formulations improve skin firmness and reduce fine lines.¹

Selenium

Selenium is incorporated into selenoproteins such as glutathione peroxidase and thioredoxin reductase, which neutralize hydrogen peroxide and lipid hydroperoxides. Selenium deficiency leads to increased oxidative stress and slower wound healing; supplementation may improve inflammatory skin disorders although excessive intake is toxic.¹

Iron

Iron is essential for hemoglobin formation and oxygen transport. Iron deficiency anemia can manifest as pallor, glossitis, brittle nails, and hair loss. However, excessive iron can catalyze the Fenton reaction, generating hydroxyl radicals that damage cellular structures. Clinicians should evaluate iron status and supplement judiciously.¹

Other Minerals

Magnesium contributes to DNA repair and regulates NMDA receptor activity, while manganese acts as a cofactor for superoxide dismutase. Silicon stimulates collagen synthesis and may improve skin hydration and elasticity; trials with choline-stabilized orthosilicic acid have shown modest improvements in hair and nails.¹

MACRONUTRIENTS AND STRUCTURAL PROTEINS

Proteins and Amino Acids

The dermis consists primarily of collagen (types I and III) and elastin, while the epidermis is rich in keratin. Dietary proteins supply essential amino acids like glycine, proline, lysine and methionine for synthesis of these structural proteins. Collagen peptides derived from bovine or marine sources have gained popularity as nutraceuticals. The

ELASTEN trial demonstrated that a drinkable supplement containing 2.5 g collagen peptides combined with vitamin C, zinc, biotin and vitamin E significantly improved skin hydration, elasticity, roughness and density compared with placebo.¹⁶ Another randomized study using 1g low-molecular-weight collagen peptides over 12 weeks showed improvements in hydration, wrinkling and elasticity.¹⁷ A more recent 16-week trial compared hydrolyzed collagen plus vitamin C with or without hyaluronic acid; both groups improved dermal density and texture, but hyaluronic acid conferred no additional benefit.¹⁵ These findings suggest that adequate dietary protein and targeted collagen supplementation can enhance extracellular matrix integrity and support postoperative recovery.

Fats and Essential Fatty Acids

Lipids compose about 15% of the stratum corneum dry weight and include ceramides, cholesterol and free fatty acids. Omega-6 linoleic acid is a precursor for ceramide biosynthesis; deficiency results in xerosis and increased transepidermal water loss. Omega-3 eicosapentaenoic acid and docosahexaenoic acid exert antiinflammatory effects by decreasing prostaglandin E2 production and inhibiting arachidonic acid metabolites. Clinical studies show that omega-3 supplementation improves acne and atopic dermatitis and may reduce photoaging. However, excessive omega-6 intake relative to omega-3 can promote inflammation. Clinicians should encourage balanced consumption of fatty fish, flaxseed, chia, walnuts, and monounsaturated fats while limiting trans fats and processed foods.¹

Carbohydrates and Glycemic Load

High glycemic index diets increase insulin and insulin-like growth factor-1, which stimulate sebaceous gland activity, androgen production and keratinocyte proliferation, aggravating acne. Hyperglycemia accelerates formation of AGEs, cross linking collagen and elastin and impairing skin elasticity.¹¹ Low-GI diets rich in whole grains, legumes, fruits and vegetables improve acne severity and may delay skin aging.^{9,11} Clinicians should counsel patients on reducing refined sugars and high-GI carbohydrates to mitigate glycation and inflammatory pathways.

XANTHOPHYLLS AND OTHER CAROTENOIDS

Astaxanthin

Astaxanthin is a marine xanthophyll carotenoid found in algae, salmon, krill, and crustaceans. It

possesses potent antioxidant and anti-inflammatory properties. Randomized clinical trials demonstrate that 4 mg/day astaxanthin for 9 weeks increases minimal erythema dose, reduces skin moisture loss after UV exposure and improves subjective skin texture.⁵ Other trials combining oral and topical astaxanthin with collagen peptides show reduced wrinkles, improved elasticity, decreased transepidermal water loss and increased procollagen I while lowering matrix metalloproteinases.⁶ Astaxanthin suppresses inflammatory mediators and enzymes such as COX-2 and iNOS.⁶ Doses of 2 to 6 mg/day are generally well tolerated; caution is advised in patients with shellfish allergies.

Lycopene

Lycopene, found in tomatoes and watermelon, accumulates in the epidermis and provides photoprotection by quenching singlet oxygen and neutralizing free radicals.^{1,9} Supplementation with tomato paste rich in lycopene has been associated with reduced UV-induced erythema in clinical studies.^{1,9} Dietary diversity ensures a balanced intake.

Lutein and Zeaxanthin

Lutein and zeaxanthin, found in leafy greens and egg yolks, accumulate in the macula and the skin. Supplementation improves hydration, elasticity and brightness and may protect against blue light-induced oxidative stress. Their photoprotective effects complement other carotenoids.^{1,6}

POLYPHENOLS AND PHYTOCHEMICALS

Polyphenols

Polyphenols are secondary plant metabolites with strong antioxidant and anti-inflammatory activities. They include flavonoids such as quercetin, catechins, anthocyanins and proanthocyanidins, and nonflavonoids such as phenolic acids, resveratrol and curcumin. Polyphenols scavenge ROS, chelate metal ions, modulate NF-κB signaling and inhibit matrix metalloproteinases.¹

Green Tea

Green tea contains catechins such as epigallocatechin gallate (EGCG) that inhibit UV-induced ROS and inflammatory mediators. Topical EGCG reduces erythema and protects against photoaging, while oral green tea phenols have been shown to modulate skin properties and microcirculation.^{18,19} Human skin studies indicate that EGCG suppresses UV-induced oxidative stress.²⁰

Cocoa Flavanols

Cocoa is rich in flavanols, including epicatechin and procyanidins. Despite theoretic benefits for vascular health, a systematic review found no significant difference in skin outcomes with chocolate consumption, likely due to short trial duration and heterogeneity.²¹ Dark chocolate contains sugar and saturated fat that may exacerbate acne; moderate consumption of cocoa powder with minimal sugar may confer antioxidant benefits.

Curcumin

Curcumin is a polyphenolic compound from turmeric with potent antioxidant and anti-inflammatory properties. It modulates NF- κ B, down-regulates COX-2, iNOS and proinflammatory cytokines, and exhibits antiglycation activity. A randomized trial using hot water extract of *Curcuma longa* showed increased epidermal water content, inhibition of UVB-induced TNF- α and IL-1 β expression and improved facial skin hydration.⁷ Because curcumin has low bioavailability, formulations such as nanoparticles or phospholipid complexes may enhance absorption.

Resveratrol and Other Polyphenols

Resveratrol from grapes activates sirtuin-1 and AMP-activated protein kinase, promoting mitochondrial biogenesis and antioxidant defense. Topical resveratrol improves fine lines and elasticity. Other polyphenols like quercetin, apigenin and rosmarinic acid inhibit tyrosinase and may reduce hyperpigmentation. Intake of polyphenol-rich foods supports skin health and complements topical antioxidants.¹

GUT-SKIN AXIS AND PROBIOTICS

The Gut-Skin Axis and Probiotics

A bidirectional communication exists between the gut microbiota and skin health. Intestinal dysbiosis can trigger systemic inflammation via increased intestinal permeability, allowing lipopolysaccharide translocation and activation of Toll-like receptor-4 with increased circulating cytokines.¹² These mediators exacerbate acne, rosacea, psoriasis and atopic dermatitis. Probiotics modulate gut microbiota composition, enhance tight junction integrity and produce metabolites that regulate immune function. In vitro studies show that probiotic extracts suppress cell cycle inhibitors, upregulate fibrillin-1 and versican and delay cellular senescence.¹² Oral administration of *Lactobacillus plantarum* and *Lactobacillus acidophilus* in animal models reduced UV-induced wrinkles, increased skin hydration and decreased matrix

metalloproteinases.¹² Human trials demonstrate that probiotics improve acne severity, reduce sebum production and enhance skin barrier function. Prebiotics and synbiotics further support microbial balance. Clinicians should recommend probiotic-rich foods such as yogurt, kefir and fermented vegetables or supplements containing *Lactobacillus* and *Bifidobacterium* strains for inflammatory skin disorders.

GLYCATION AND ANTIGLYCATION STRATEGIES

Glycation and Antiglycation Strategies

The Maillard reaction between reducing sugars and proteins leads to AGE formation, which accumulates in the dermis, cross linking collagen and elastin and reducing skin elasticity.¹¹ AGEs also activate receptor-mediated signaling, increasing oxidative stress and inflammation. Dietary sugars and thermal processing of food contribute significantly to exogenous AGEs; high-temperature cooking produces more AGEs than boiling or steaming. To mitigate glycation, patients should reduce consumption of sugary beverages, processed foods and charred meats, and increase intake of fruits, vegetables and herbs rich in natural antioxidants and anti-glycation compounds. Phytochemicals such as flavonoids, phenolic acids and carnosine act as carbonyl scavengers or metal chelators, reducing AGE formation.¹¹ Maintaining good glycemic control and adopting a low-glycemic diet are practical strategies for preserving skin suppleness.

MELATONIN AND CIRCADIAN RHYTHMS

Melatonin and Circadian Rhythms

Melatonin is a hormone synthesized in the pineal gland and in skin cells. It regulates circadian rhythms and has potent antioxidant and anti-inflammatory properties. Melatonin scavenges ROS and reactive nitrogen species, upregulates antioxidant enzymes and modulates mitochondrial function. In the skin, melatonin receptors are expressed in keratinocytes, melanocytes, fibroblasts and hair follicles. Recent research highlighted that melatonin and vitamin D may act synergistically in the skin, with melatonin protecting against UV-induced oxidative stress while vitamin D regulates proliferation and differentiation.⁸ Melatonin has been investigated for photoprotection; topical melatonin applied before UV exposure reduces erythema.²² Oral melatonin also inhibits UV-induced cytokine production, reduces MMP-1 expression and enhances repair of DNA lesions.⁸ Oral supplementation may improve sleep quality, which indirectly influences skin

health via cortisol reduction. Clinicians should consider melatonin in photoprotection regimens and advise patients on maintaining healthy circadian rhythms through consistent sleep schedules and limiting evening exposure to blue light.

NUTRITIONAL INTERVENTIONS FOR SKIN DISORDERS

Nutritional Interventions for Skin Disorders

Nutrients can be therapeutic adjuncts in managing inflammatory skin conditions. In rosacea, oral isotretinoin is effective for papulopustular disease but is teratogenic and may cause mucocutaneous side effects.¹⁴ Niacinamide creams and oral NADH have shown benefit with fewer adverse events.¹⁴ Oral zinc sulfate reduced inflammatory lesions in one clinical trial but had no effect in another; topical zinc sulfate solution achieved moderate to good responses.¹⁴ Omega-3 fatty acids improved ocular rosacea symptoms in clinical studies.¹⁴ In acne vulgaris, zinc, probiotics and low-glycemic diets reduce lesion counts.^{4,9,12} Atopic dermatitis may benefit from probiotics, vitamin D and zinc supplementation. Psoriasis and vitiligo have been linked to low levels of vitamin D, selenium and folate; antioxidant supplementation and gluten-free diets may offer additional benefit.⁹ Androgenetic alopecia has been associated with deficiencies in iron, zinc, vitamin D, and essential amino acids; nutritional correction can complement pharmacologic therapy. Patients should be counseled that supplements are adjuncts rather than replacements for medical treatment.

Diet and Lifestyle

Diet and lifestyle

While individual nutrients play critical roles, overall dietary pattern and lifestyle factors exert the greatest influence on long-term skin health. A Mediterranean-style diet rich in fruits, vegetables, whole grains, legumes, nuts, olive oil and fish provides an abundance of antioxidants, polyphenols, carotenoids, vitamins and essential fatty acids.⁹ Observational studies associate this diet with lower rates of photoaging and inflammatory dermatoses. In contrast, Western diets high in refined carbohydrates, processed meats and saturated fats promote inflammation, oxidative stress and glycation. Adequate hydration improves skin turgor and reduces roughness.²³ Chronic sleep deprivation impairs barrier recovery and is associated with accelerated signs of cutaneous aging.²⁴ Smoking should be discouraged due to its deleterious effects on collagen and microvasculature.²⁵ These measures complement specific nutrient interventions to optimize skin and hair outcomes.

SUMMARY

Nutritional biologics offer a powerful adjunct to surgical and regenerative procedures by modulating fundamental pathways of skin and hair biology. A balanced intake of vitamins, minerals, proteins, essential fatty acids and phytonutrients supports keratinocyte differentiation, collagen synthesis, antioxidant defense, and immune regulation. Clinical trials demonstrate that collagen peptides, astaxanthin, curcumin, probiotics and hyaluronic acid supplements can improve hydration, elasticity, wrinkle depth and barrier function.^{5,7,12,15–17} Understanding the gut-skin axis, glycation processes and circadian rhythms expands therapeutic opportunities. In practice, clinicians should assess patients' nutritional status, encourage a diverse, plant-rich diet and consider targeted supplementation when deficiencies are identified. Personalized nutritional interventions, integrated with aesthetic treatments, can enhance patient outcomes, minimize complications and contribute to overall well-being. Future research should focus on standardized trials, bioavailability of nutraceuticals and the synergistic effects of combined therapies.

During the preparation of this work the authors used Gen AI. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

DISCLOSURE

None.

REFERENCES

1. Michalak M, Pierzak M, Kręcis B, et al. Bioactive compounds for skin health: a review. *Nutrients* 2021;13(1):203. PMID: 33445474; PMCID: PMC7827176.
2. Pullar JM, Carr AC, Vissers MCM. The roles of vitamin C in skin health. *Nutrients* 2017;9(8):866. PMID: 28805671; PMCID: PMC5579659.
3. VanBuren CA, Everts HB. Vitamin A in skin and hair: an update. *Nutrients* 2022;14(14):2952. PMID: 35889909; PMCID: PMC9324272.
4. Zou P, Du Y, Yang C, et al. Trace element zinc and skin disorders. *Front Med (Lausanne)* 2023;9:1093868.
5. Ito N, Seki S, Ueda F. The protective role of astaxanthin for UV-Induced skin deterioration in healthy People-A randomized, double-blind, placebo-controlled trial. *Nutrients* 2018;10(7):817. PMID: 29941810; PMCID: PMC6073124.
6. Björklund G, Gasmi A, Lenchyk L, et al. The role of astaxanthin as a nutraceutical in health and age-

- related conditions. *Molecules* 2022;27(21):7167. PMID: 36363994; PMCID: PMC9655540.
7. Asada K, Ohara T, Muroyama K, et al. Effects of hot water extract of *Curcuma longa* on human epidermal keratinocytes in vitro and skin conditions in healthy participants: a randomized, double-blind, placebo-controlled trial. *J Cosmet Dermatol* 2019;18(6):1866–74. Epub 2019 Feb 27. PMID: 30809971.
 8. Simon JA, Serrano C, Kumar D, et al. Beyond sleeping disorders, the role of melatonin in skin diseases and emerging applications in dermatology and topical therapy. *Gels* 2025;11(11):860. PMID: 41294545; PMCID: PMC12652500.
 9. Cao C, Xiao Z, Wu Y, et al. Diet and skin aging-from the perspective of food nutrition. *Nutrients* 2020;12(3):870. PMID: 32213934; PMCID: PMC7146365.
 10. Dähnhardt D, Dähnhardt-Pfeiffer S, Segger D, et al. Restoration of the ultrastructural integrity of the dermal collagen network by 12-Week ingestion of special collagen peptides. *Dermatol Ther (Heidelb)* 2024;14(9):2509–21. Epub 2024 Aug 16. PMID: 39150674; PMCID: PMC11393225.
 11. Zheng W, Li H, Go Y, et al. Research advances on the damage mechanism of skin glycation and related inhibitors. *Nutrients* 2022;14(21):4588. PMID: 36364850; PMCID: PMC9655929.
 12. Gao T, Wang X, Li Y, et al. The role of probiotics in skin health and related gut-skin axis: a review. *Nutrients* 2023;15(14):3123. PMID: 37513540; PMCID: PMC10385652.
 13. Januszewski J, Forma A, Zembala J, et al. Nutritional supplements for skin Health-A review of what should be chosen and why. *Medicina (Kaunas)* 2023;60(1):68. PMID: 38256329; PMCID: PMC10820017.
 14. Algarin YA, Pulumati A, Jaalouk D, et al. The role of vitamins and nutrients in rosacea. *Arch Dermatol Res* 2024;316(5):142. PMID: 38695936; PMCID: PMC11065919.
 15. Žmitek K, Žmitek J, Hristov H, et al. The effects of dietary supplementation with collagen and vitamin C and their combination with hyaluronic acid on skin density, texture and other parameters: a randomised, double-blind, placebo-controlled trial. *Nutrients* 2024;16(12):1908. PMID: 38931263; PMCID: PMC11206740.
 16. Bolke L, Schlippe G, Gerß J, et al. A collagen supplement improves skin hydration, elasticity, roughness, and density: results of a randomized, placebo-controlled, blind study. *Nutrients* 2019;11(10):2494. PMID: 31627309; PMCID: PMC6835901.
 17. Kim DU, Chung HC, Choi J, et al. Oral intake of low-molecular-weight collagen peptide improves hydration, elasticity, and wrinkling in human skin: a randomized, double-blind, placebo-controlled study. *Nutrients* 2018;10(7):826. PMID: 29949889; PMCID: PMC6073484.
 18. Heinrich U, Moore CE, De Spirt S, et al. Green tea polyphenols provide photoprotection, increase microcirculation, and modulate skin properties of women. *J Nutr* 2011;141(6):1202–8. Epub 2011 Apr 27. PMID: 21525260.
 19. Elmets CA, Singh D, Tubesing K, et al. Cutaneous photoprotection from ultraviolet injury by green tea polyphenols. *J Am Acad Dermatol* 2001;44(3):425–32.
 20. Katiyar SK, Afaq F, Perez A, et al. Green tea polyphenol (-)-epigallocatechin-3-gallate treatment of human skin inhibits ultraviolet radiation-induced oxidative stress. *Carcinogenesis* 2001;22(2):287–94. PMID: 11181450.
 21. Tan TYC, Lim XY, Yeo JHH, et al. The health effects of chocolate and cocoa: a systematic review. *Nutrients* 2021;13(9):2909. PMID: 34578786; PMCID: PMC8470865.
 22. Bangha E, Elsner P, Kistler GS. Suppression of UV-induced erythema by topical treatment with melatonin (N-acetyl-5-methoxytryptamine). Influence of the application time point. *Dermatology* 1997;195(3):248–52.
 23. Palma L, Marques LT, Bujan J, et al. Dietary water affects human skin hydration and biomechanics. *Clin Cosmet Invest Dermatol* 2015;8:413–21. PMID: 26345226; PMCID: PMC4529263.
 24. Altemus M, Rao B, Dhabhar FS, et al. Stress-induced changes in skin barrier function in healthy women. *J Invest Dermatol* 2001;117(2):309–17. PMID: 11511309.
 25. Morita A. Tobacco smoke causes premature skin aging. *J Dermatol Sci* 2007;48(3):169–75.