

Review

The “Maskne” microbiome – pathophysiology and therapeutics

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Abstract

“Maskne” is a new term coined during the 2020 COVID-19 pandemic. It refers to a subset of acne mechanica, deserving consideration in view of widespread reusable fabric mask-wearing to control the pandemic worldwide. Understanding of underlying pathophysiology directly relates to the novel skin microenvironment and textile–skin friction created by mask-wearing, distinct from nontextile-related acne mechanica previously linked to wearing of headgear. Specifically, the occlusive microenvironment leads to microbiome dysbiosis, which is linked to various dermatological conditions. Additional textile–skin interactions include factors such as breathability, stickiness sensations, moisture saturation, and hygiene maintenance. Increased skin temperatures can trigger sweat/heat-related dermatoses, and ear loops potentially trigger pressure-induced dermatoses. Important therapeutic considerations include increased skin irritation potential of conventional acne treatments under occlusion, exacerbation of chronic dermatoses, that is, perioral dermatitis, rosacea, and eczema, and susceptibility of these same patient groups to heightened discomfort with mask-wearing. Cotton, as the traditional fabric of choice for dermatology patients, has limited benefits in the context of face masks – increased subjective discomfort relates to increased moisture saturation and stickiness, inevitable because of high biofluid load of the nasal and oral orifices. Prolonged textile–skin contact time, directly proportional to the risk of maskne, can be an opportunity for the application of biofunctional textiles.

COVID-19, a respiratory disease caused by the SARS-CoV-2 virus, was declared a pandemic by the World Health Organization (WHO) on March 11, 2020. In light of estimates that approximately one half of new infections are transmitted by persons who have no symptoms, universal mask-wearing has become one of the public health recommendations critical to reducing respiratory transmission of SARS-CoV-2 virus.

Mask acne or “maskne”¹, which has arisen during the 2020 COVID-19 pandemic, refers to a form of acne mechanica arising from textile–skin friction. “Maskne” is deserving consideration in view of widespread reusable textile mask-wearing to limit the spread of biofluids and, hence, the risk of contagion because of environmental contamination. Skin microbiota is influenced by genetic and external factors such as environment, pH, and temperature,² all of which are modified with mask-wearing and retention of biofluids. This review paper addresses the impact of fabric mask-wearing on the skin microbiome and dermatological conditions as well as the therapeutic role of biofunctional textiles in improving the skin microenvironment. A textile is defined as any material that is woven. These materials can be synthetic (i.e., plastic-derived) or natural fibers (i.e., cotton, linen, and silk). The scope of this review also includes

synthetic textiles such as polyester, that is, plastic-derived types of materials, which are also identified as textiles.

Skin microbiome

1 Bacteria: The disruption of the healthy skin microbiome associated with mask-wearing has profound implications on several dermatological conditions such as eczema,³ acne,⁴ and perioral dermatitis,⁵ with bacterial dysbiosis implicated in its pathogenesis. *Staphylococcus aureus* colonization has a well-established superantigen effect on eczema flare-ups and has been implicated in various studies involving acne pathogenesis.⁴ Gram-negative folliculitis is a common complication of acne and can result in pustular eruptions and requires treatment with broad-spectrum antibiotics. Our latest understanding of acne pathogenesis has shifted from *Propionibacterium acnes* to *Cutibacterium acnes* (*C. acnes*) colonization of sebaceous follicles. Dysbiosis of the skin microbiota leads to selection of virulent and pathogenic *C. acnes* strains and activation of innate immunity causing cutaneous inflammation.⁶ Fusobacteria has been implicated in the pathogenesis

of perioral dermatitis successfully treated with β -lactam antibiotics in those who were tetracycline-intolerant.⁷

- 2 Fungal organisms:** Proliferation of *malassezia furfur*, otherwise a healthy skin commensal, plays an important etiopathogenic role in the development of seborrheic dermatitis⁸ as well as *pityrosporum folliculitis*, a clinical mimic of acne.^{9,10}
- 3 Others:** There is a statistically significant association between demodex mite density and rosacea.^{11–13} The emergence of ivermectin as a key therapy for rosacea supports the role of Demodex mites in the etiopathogenesis of rosacea. An altered skin microbiome will influence the interaction of demodex with various microorganisms, affecting the host immune system modulation response.^{11–13}

Dermatoses associated with heat/sweat

Fabric mask wear will increase skin temperatures and lead to increased sweat retention in normal individuals and worsen symptoms in those with facial hyperhidrosis.¹⁴ Sweat allergy plays a role in the exacerbation of atopic dermatitis (AD) because of specific IgE-mediated (type 1) hypersensitivity to sweat contents.¹⁵ The effects of increased skin temperature can trigger conditions such as miliaria rubra and cholinergic urticaria. The moist warm microenvironment created by mask-wearing increases the susceptibility of skin to fungal/yeast infections including candidiasis and malassezia, both common commensals of healthy skin. Intertrigo^{16,17} traditionally associated with flexural areas, such as digital web spaces, axilla, groin, and inframammary folds, can be caused by microorganism overgrowth and is exacerbated by frictional dermatitis. Causative organisms implicated include candida, group A beta-hemolytic streptococcus,¹⁸ *Corynebacterium minutissimum*, and *Pseudomonas aeruginosa*.^{16,19} Mask-wearing potentially introduces a "new" intertriginous area which is susceptible to similar infections, in particular with microbial communities like *Staphylococcus* and *Corynebacteria*, which favor moist regions.²

Allergic contact dermatitis and harmful chemical exposure associated with textiles

The widespread manufacturing of various types of fabric face masks is to be regarded as part of the largely unregulated garment industry, with regard to fabric safety/skin tolerability, in contrast to personal protective equipment. It is reasonable to hypothesize that textile dyes will influence the development of allergic contact dermatitis over areas in contact with the face mask. Disperse dyes are a leading cause of textile-related allergic patch test positivity.²⁰ Given the close proximity and occlusive effect of the mask to facial skin and the nasal and oral mucosal passages, as well as the use of potentially allergenic dispersed dyes in garment textiles, it may be prudent to consider dermatological recommendations for fabrics used for face masks. Existing textile certification bodies currently exist but are

not mandated for manufacturers of face masks. This is in line with regulation of cosmetic products used in the personal care market, that is, the Personal Care Products Safety Act, which allows tracking, reporting of adverse events as well as the care of patients who are uniquely vulnerable to certain chemicals.²¹ Benzothiazole, its derivatives, and other potentially hazardous chemicals are common textile contaminants in the garment industry. Using an artificial skin mimicking model membrane, Strat-M®, a study by Iadaresta *et al.*²² in 2018 demonstrated that benzothiazole, a carcinogen (also applied to other chemical contaminants), was released from textile materials, where it subsequently penetrated through the skin and further entered the human body systemically. Textile contaminants are potential health risks via dermal permeation to reach the systemic circulation.²³

Therapeutic considerations

- 1 Cleansing:** Gentle cleansers with antibacterial active ingredients for maintenance of a healthy skin microbiome.
- 2 Leave-on skincare:** Avoid alcohol, salicylic acid, alpha-hydroxy acids, and retinols in leave-on acne skincare formulations because of increased risk of irritant contact dermatitis under prolonged occlusion.
- 3 Moisturizers:** Serum, mist, lotion, and cream-based vehicles, preferred over ointments. Moisturizers are essential in the maintenance of a healthy skin barrier function and reduce disruption of the skin microbiome, besides acting as a shield against external triggers. Humectants and "Prescription Emollient Devices (PEDs)"²⁴ should be the standard of care for moisturizers as opposed to emollient or occlusive active ingredients. Examples of PEDs include optimal ceramide/lipid mixtures with anti-inflammatory ingredients such as glycyrrhetic acid. Traditional humectants containing lactic acid and urea should be avoided, as these interact with sweat and moisture to alter the pH of skin under occlusion, resulting in irritant contact dermatitis. Examples of humectants that reduce transepidermal water loss without any irritation when worn under occlusion are natural moisturizing factors, sodium hyaluronate, and polyglutamic acid. Occlusives (e.g., petrolatum, mineral oil, and dimethicone) and emollients (lanolin, glycerol stearate, glyceryl stearate, and soy sterols) can both trigger occlusion acne in the case of maskne. For individuals with hyperhidrosis, excessive oily, acne-prone skin, cream to powder moisturizer formulas may be helpful in maintaining an intact skin barrier to prevent skin inflammation under occlusion.²⁵
- 4 Topical acne treatments:** Chemical/synthetic active ingredients, such as benzoyl peroxide, salicylic acid, sulfur, alpha-hydroxy acids, and retinoids, have a higher risk of inducing irritant contact dermatitis under occlusive face mask wear. In addition, benzoyl peroxide has a bleaching effect on fabrics.

Evidence-based botanical active ingredients, which work via anti-inflammatory effects, regulation of sebum production, and broad-spectrum antimicrobial activity, are recommended for maskne treatment.¹ Use of powder formulations for acne may be preferred under occlusion to absorb excess moisture,²⁵ especially in individuals with facial hyperhidrosis. Zinc oxide formulations have broad antimicrobial properties effective for prevention and treatment of acne, and are stable in powder formulations.²⁶ Hydrogel carrier formulations of retinoid/antibiotic combination topicals can minimize local irritation by ensuring better drug tolerance and efficacy²⁷ in addition to providing an optimal wound healing environment. It may also provide effective barrier protection to reduce skin–textile friction and secondary bacterial infection.

5 Sunscreen: Current recommendations of broad-spectrum SPF 50+ topical sunscreen and its 3–4 hourly reapplication rate are impractical under long periods of face mask wear especially outdoors. Chemical sunscreens can induce sensitization because of photodegradation, worse in individuals with atopy²⁸ when in contact with sweat/moisture under occlusion. Water-resistant sunscreen with high lipophilic/hydrophilic ratios increases comedogenicity.^{28,29} Ultraviolet protective (UPF) 50+ fabrics used for mask wear should be the principal intervention for broad-spectrum sun protection for the lower half of the face during the COVID-19 pandemic,¹ to improve patient compliance to photoprotection and incentivize mask-wearing, also eliminating periodic reapplication of sunscreens.

6 Impact of face mask material/design on skin microenvironment

a Textile–skin interactions: Natural fibers, such as cotton, linen, silk, and lyocell, offer greater breathability compared to synthetic fibers by wicking moisture away from skin. These may be beneficial for keeping the surface of skin dry and reducing microorganism overgrowth. However, natural fibers increase saturation levels. This increases symptoms of discomfort and weight. The perceived stickiness of the fabric can be measured by accumulated stickiness magnitude, ASM.³⁰ Synthetic fabrics that have been treated for cooling coefficient, moisture, and air permeability, also known as biofunctional textiles,³¹ have a high evaporation coefficient without the fabric weighing down, an important factor in ensuring comfort. Sensitive skin possesses heightened neurosensory input that increases susceptibility to cutaneous sensory stimulants.³² Textile–skin friction is an established trigger for several dermatological conditions, that is, AD, acne mechanica, frictional dermatitis, and postinflammatory hyperpigmentation. It may worsen symptoms in inflammatory conditions such as seborrheic dermatitis, perioral dermatitis, and rosacea. Fabrics with lower thread count as opposed to those with higher thread count will cause increased friction against skin. The fabric should have a smooth surface and a tight

weave rather than loose weaves, which cause an irregular surface. Tightly woven fabrics also innately have higher UPF. Dark colors retain heat and increase skin temperature, which affects skin comfort and worsens heat-sensitive conditions such as AD, cholinergic urticaria, hyperhidrosis, miliaria rubra, and rosacea.

b Design: A smooth-surfaced design with minimal folds is recommended¹ for minimal textile–skin friction, with a drawstring ear loop system to allow for individual adjustment. The surgical mask pattern with expandable folds accommodates various head sizes and face shapes but is not comfortable in the form of thicker textiles (used in reusable fabric masks) following the same pattern. The increased stitching and seams involved in creating the folds may reduce durability. To allow for maximal breathability and comfort while speaking, a pattern with two separate panels of the fabric follows the contour of the nose bridge and allows for comfortable air movement around the nose while minimizing spread of droplets. Based on the principle of an ideal fabric face mask offering UPF protection, the design facilitates maximum coverage of available facial skin surface area, consistent with current European recommendations for the design of UV-protective clothing.³³

c Contact dermatitis: Metallic nasal bridges offer no additional function and can cause nickel sensitization/contact allergy to the metal piece.³⁴ Ear loops should be latex-free³⁵ alternatives such as spandex (polyurethane polymer). Adjustable rather than stretchable properties are preferred to avoid pressure and friction on the retroauricular region when worn for prolonged periods. This can predispose or aggravate abrasions, frictional dermatitis, postinflammatory hyperpigmentation, flexural eczema, and pressure dermographism. Rather than elastics, an adjustable threadable flat-surfaced bead can be used to hold the face mask loops in place, a variant of a drawstring system.¹ Spherical beads protrude on skin and can cause frictional dermatitis. Drawstring forms of adjustable ear loops are preferred over ribbon ties, as these are prone to slip off, reduce a snug fit of the face mask, and cannot be quickly re-worn in common social circumstances.

d Hygiene: Reusable fabric mask wear poses the practical challenge of how to hygienically store the mask when one is exercising, eating, or drinking. To increase compliance of face mask-wearing for the general public, immediately before/after the said activities, doctors can recommend the quick act of looping it under the jawline (vs. storage in a separate bag) (Fig. 1). This provides a natural hold, minimizing risks of mask dislocation and need for constant adjustment (i.e., surface contamination). Given the daily wear of the face mask and contamination with respiratory droplets and saliva, the face mask should withstand daily laundering at high temperatures to destroy microorganisms that cause odor/disease. Synthetic fibers like polyester and

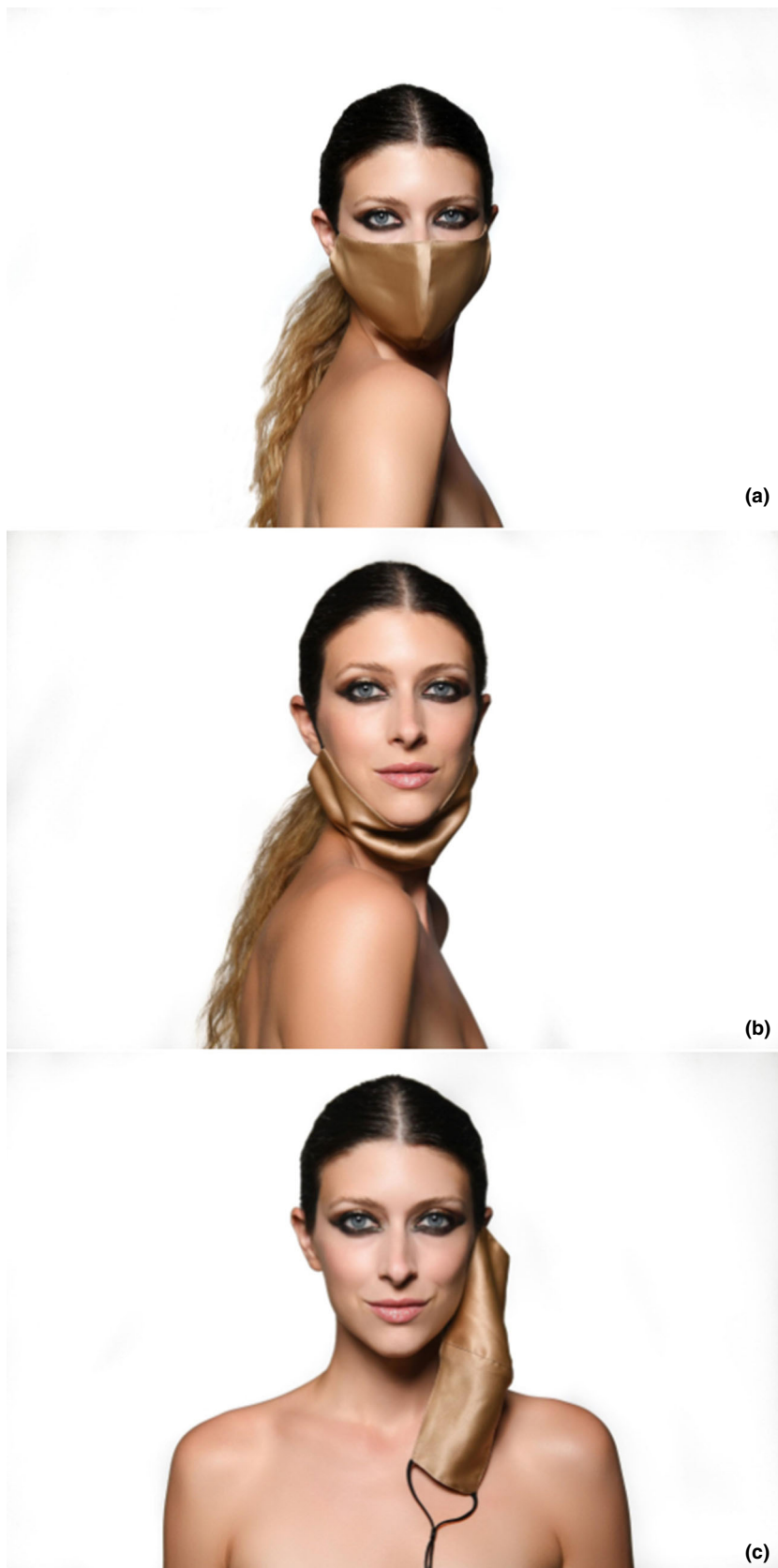


Figure 1 Proposed method of mask handling when eating/drinking/exercising. (a) The fabric face mask for public use should cover the nose and the mouth when worn, for protection of the environment from biofluid contamination. (b) When eating/drinking/exercising, the mask can be conveniently looped under the jawline which forms a natural hold for storage, minimizing the risk of further contamination and enabling quick re-wearing. (c) Dangling a mask off one side of face while performing said activities is not recommended as it exposes biofluid for potential contamination of the environment

polyurethane are more durable than natural fibers, the latter prone to distortion/disintegration, affecting efficacy. For hygienic and convenient disinfection of fabric masks when daily washing is not possible, applying a hot iron (356–428 Fahrenheit at standard settings) on both sides of the fabric will be sufficient to kill respiratory viruses, including the COVID-19 virus³⁶ as well as minimize pathogenic bacterial growth. Biofunctional textiles confer self-cleaning benefits relevant for a frequent wear, high biofluid contamination garment like the reusable fabric mask.³⁷

7 Distinct complications from systemic pharmacotherapy:

The use of traditional systemic pharmacotherapy for moderate or severe maskne may face unique complications distinct from acne vulgaris. The side effect profile of isotretinoin, a widely used systemic medication for the treatment of moderate/severe acne, includes development of eczema, cheilitis, and increased bacterial infections, that is, *S. aureus*.³⁸ Individuals on isotretinoin are prone to frictional dermatitis, exacerbation of retinoid dermatitis, cheilitis, and are more susceptible to cutaneous infections.³⁹ The warm and moist microenvironment increases the risk of microorganism overgrowth and secondary infections, such as impetigo, Gram-negative folliculitis, and malassezia folliculitis.

Potential of biofunctional textiles in microbiome dysbiosis

Given that textiles have prolonged contact with skin, research into functional textiles with intrinsic properties, such as antioxidative capacity and antimicrobial activity, will be relevant in dermatological applications. The current recommendation of the widespread use of reusable fabric masks is one such area.

Traditionally, dermatologists have recommended cotton as the only comfortable tissue suitable for patients with dermatological conditions. With the advancement of materials engineering, synthetic fibers with improved functions of breathability and waterproofing, and the added properties of quick-dry, increased comfort (compared to cotton), surface modification with antimicrobial properties, have emerged as a complementary tool in dermatologic treatments.⁴⁰ Functional textiles (that maintain deliverable antimicrobial activity *in vitro*)⁴¹ have been proposed as safe adjunct treatment for AD with some data published regarding their antimicrobial properties and clinical efficacy.^{42–45}

Relevant biofunctional textiles to dermatology were reviewed, via a search over the following databases, i.e. PubMed, ScienceDirect, and Google Scholar. The key words such as "textile dermatology", "textile skin", "zinc textile", "zinc oxide textile", "zinc textile dermatology", "copper textile", "copper oxide textile", "copper textile dermatology", "silver textile", "silver textile dermatology", "antibacterial textile", "UV textile", "antiaging textile", "textile nanoparticles", "atopic dermatitis textile", "eczema textile", and "acne textile" were utilized. A separate search with the word "textile" replaced by "fabrics" was also executed. All

studies published over a 10 year duration from 2010 till September 2020 were analyzed.

Study selection. Studies describing synthesis of nanoparticles on textiles with subsequent analysis of acquired functions and studies containing clinical evidence of the effect of textiles impregnated with nanoparticles on skin condition were included into this review.

Study characteristics. All studies were analyzed with regard to the nature of nanoparticles utilized for textile modification, the type of textile, and the efficacy of modified textile in terms of its antimicrobial, antifungal, antiviral activity, UV protection, or anti-aging properties. The results of individual studies were used *per se* and not analyzed (Table 1).

Silver impregnated textiles exhibited significantly less *S. aureus* as well as total bacterial colonization after 2 days of wearing without washing, as compared with a placebo textile.⁴⁶ In a randomized controlled trial, silver-loaded seaweed fiber was associated with an *in vivo* statistically significant reduction in *S. aureus* colonization and a pronounced improvement in barrier function (transepidermal water loss).⁴⁷ Given the pathophysiologic similarities of bacterial proliferation and chronic inflammation in both acne and hidradenitis suppurativa, Morand *et al.* treated a case of hidradenitis suppurativa with silver-coated textiles with reported success.⁴⁸ ZnO-functionalized textile fibers were associated with rapid improvement of AD severity, pruritus, and subjective sleep quality when AD patients wore the ZnO textiles,⁴⁹ postulated to be related to high antioxidative capacity of the ZnO textile, strong antibacterial activity, and good biocompatibility. Nanocrystalline silver dressings have demonstrated statistically significant wound healing benefits over traditional silver sulfadiazine and gauze dressings, because of its anti-inflammatory effect.⁵⁰

Copper oxide impregnated textiles are broadly biocidal, self-sterilizing, with efficacy against antibiotic-resistant bacteria, including methicillin-resistant *S. aureus* and vancomycin-resistant *Enterococci* when used in the control of nosocomial infections and the spread of antibiotic-resistant bacteria.⁵¹ Impregnation of copper oxide into respiratory protective face masks also confers additional biocidal properties (anti-influenza) apart from its inherent filtration properties and can significantly reduce the risk of hand or environmental contamination, and subsequent infection, because of improper handling and disposal of the masks.⁵² Examples in dermatological applications include incorporation in antifungal socks for treatment of tinea pedis and anti-demodex mite mattress covers for prevention of dust mite-triggered allergies, with no demonstrable skin-sensitizing properties.⁵¹

Antibiotic resistance is an important concept in acne treatment, and it is currently recommended to use topical antibiotics in combination with benzoyl peroxide or retinoids to lower antibiotic resistance of *P. acnes* to erythromycin and clindamycin.⁵³ However, such formulations when worn under occlusive effects will increase the risk of irritant contact dermatitis. Given the

Table 1 Review of *in vitro* and *in vivo* studies involving biofunctional textiles with antimicrobial properties

Reference	Material	Effect
Textiles modified by Zn compounds		
<i>In vitro</i> studies		
Pandimurugan <i>et al.</i> (2017) ⁵⁴	ZnO NPs/cotton	Inhibits <i>S. aureus</i> , <i>S. pyogenes</i> , <i>E. coli</i> and <i>K. aerogenes</i>
Ghasemi <i>et al.</i> (2018) ⁵⁵	ZnO NPs/cotton	Inhibits <i>S. aureus</i> and <i>E. coli</i>
Khan <i>et al.</i> (2018) ⁵⁶	ZnO NPs/cotton	Inhibits <i>E. coli</i> and <i>S. aureus</i> and preserves UV properties up to 20 washing cycles
D'Agua <i>et al.</i> (2018) ⁵⁷	ZnO NPs/cotton	Inhibits MRSA, <i>S. epidermidis</i> , <i>S. aureus</i> and <i>P. acnes</i>
Shaheen <i>et al.</i> (2016) ⁵⁸	ZnO NPs/cotton	Inhibits <i>S. aureus</i> and <i>E. coli</i>
Souza <i>et al.</i> (2018) ⁵⁹	ZnO NPs/cotton	Inhibits <i>S. aureus</i> and <i>P. aeruginosa</i>
Ran <i>et al.</i> (2018) ⁶⁰	ZnO NPs/cotton	Inhibits <i>G. cerinus</i>
Salat <i>et al.</i> (2018) ⁶¹	ZnO NPs/cellulose	Inhibits <i>S. aureus</i> after 60th laundry
Wang <i>et al.</i> (2016) ⁶²	ZnO NPs/cotton	Inhibits <i>S. aureus</i> and <i>K. pneumoniae</i> . UPF 50+
Petkova <i>et al.</i> (2016) ⁶³	ZnO NPs/cotton	Inhibits <i>S. aureus</i> and <i>E. coli</i>
El-Nahhal <i>et al.</i> (2020) ⁶⁴	ZnO NPs/cotton	Increases antimicrobial activity toward <i>S. aureus</i> and <i>E. coli</i>
Das <i>et al.</i> (2017) ⁶⁵	ZnO NPs/cotton	Inhibition of <i>E. coli</i> and <i>S. aureus</i>
Kar <i>et al.</i> (2019) ⁶⁶	ZnO NPs/cotton Khadi	Inhibits <i>K. pneumoniae</i> and <i>S. aureus</i> . UPF 20
Huang <i>et al.</i> (2019) ⁶⁷	ZnO NPs/silk	Has UPF >50
Nourbakhsh <i>et al.</i> (2018) ⁶⁸	ZnO NPs/polyester	Inhibits <i>S. aureus</i> and <i>E. coli</i>
Ashraf <i>et al.</i> (2016) ⁶⁹	ZnO NPs/polyester, cotton	Inhibits <i>S. aureus</i>
Paul <i>et al.</i> (2019) ⁷⁰	ZnSnO ₃ /cotton	Inhibits Gram-positive and Gram-negative bacteria with UPF 45
Amani <i>et al.</i> (2019) ⁷¹	ZnO NPs/polyester	Inhibits <i>E. coli</i> , <i>S. aureus</i> and <i>C. albicans</i>
Preethi <i>et al.</i> (2020) ⁷²	ZnO NPs/cotton	Inhibits <i>S. aureus</i> , <i>B. subtilis</i> and <i>E. coli</i>
Fiedot-Tobola <i>et al.</i> (2018) ⁷³	ZnO microparticles/polyethylene terephthalate, polyamide, polypropylene	Inhibits <i>E. coli</i> and <i>S. aureus</i>
Hassabo <i>et al.</i> (2019) ⁷⁴	Ag NPs/ZnO NPs/Cu NPs/cotton	Durable antibacterial and UV protection properties.
Holt <i>et al.</i> (2018) ⁷⁵	ZnCl ₂ /polyester	Inhibits <i>S. aureus</i> even after abrasive washing
<i>In vivo</i> studies		
Wollina <i>et al.</i> (2009) ⁷⁶	Smartcel sensitive (ZnO NPs/cotton, lycell, elastane)	Sleep improvement and pruritus alleviation was observed in neurodermatitis patients after 10 days
Hoefler <i>et al.</i> (2018) ⁷⁷	Smartcel sensitive (ZnO NPs/cotton, lycell, elastane); Benevit Zinc+ (lyocell, ZnO NPs/Smartcel sensitive, spandex); DermaSilk (AEGIS 5772/silk); Padycare (polyamide, Ag NPs/lycra); Binamed (modal, Ag NP/polyester, lycra)	ZnO-containing fabrics have stronger antibacterial activity than Ag-containing samples, which are more effective in decreasing lesion severity, while silk fabrics alleviate pruritus and symptoms
Wiegand <i>et al.</i> (2013) ⁴⁹	Benevit Zink+ (lyocell, ZnO NPs/Smartcel sensitive, spandex)	Improved night sleep, pruritus, and AD severity
Textiles modified by Cu compounds		
<i>In vitro</i> studies		
Teli <i>et al.</i> (2013) ⁷⁸	Cu NPs/bamboo rayon	Inhibits <i>S. aureus</i> and <i>E. coli</i> after 50 washes
Hammer <i>et al.</i> (2012) ⁷⁹	Cu NPs/cotton	Inhibits <i>T. rubrum</i> , <i>T. mentagrophytes</i> and <i>C. albicans</i>
Sharma P <i>et al.</i> (2019) ⁸⁰	Cu NPs/cotton	Inhibits <i>S. aureus</i> and <i>E. coli</i>
Turalija <i>et al.</i> (2015) ⁸¹	Cu ₂ O microparticles/polyester	Inhibits <i>S. aureus</i> and <i>K. pneumoniae</i>
Bhutiya PL <i>et al.</i> (2018) ⁸²	Cu ₂ O NPs/cellulose	Inhibits <i>S. aureus</i> , <i>S. thermophilus</i> , <i>P. aeruginosa</i> and <i>E. coli</i>
Vasantharaj S <i>et al.</i> (2019) ⁸³	CuO NPs/cotton	Inhibits <i>S. aureus</i> , <i>E. coli</i> , <i>K. pneumoniae</i>
Galani <i>et al.</i> (2016) ⁸⁴	Cu NPs/para-aramide and polyester	Inhibits <i>S. aureus</i> , <i>K. pneumoniae</i> , <i>P. aeruginosa</i> , <i>A. baumannii</i> and <i>E. faecium</i> , <i>P. aeruginosa</i> and <i>C. parapsilosis</i>
Sójka-Ledakowicz <i>et al.</i> (2016) ⁸⁵	CuSiO ₃ /polypropylene and polylactide	Inhibits <i>E. coli</i> , <i>S. aureus</i> and <i>C. albicans</i>
Imai K <i>et al.</i> (2012) ⁸⁶	Cu ²⁺ /cotton	Inactivates avian influenza virus H5 subtype
<i>In vivo</i> studies		
Marcus <i>et al.</i> (2017) ⁸⁷	CuO NPs/linen, cotton and polyester	Reductions of 29.3, 55.5, 23.0, and 27.5% in the ATIEs, fever days, days of antibiotic treatment, and antibiotics.

Table 1 Continued

Reference	Material	Effect
Butler (2018) ⁸⁸	CuO NPs/linen, cotton and polyester	~48% reductions in HCAI caused by <i>C. difficile</i> , ~32% reductions in HCAI caused by MDROs, and ~45% in the reduction of HCAI caused by <i>C. difficile</i> and MDROs combined
Lazary <i>et al.</i> (2014) ⁸⁹	CuO NPs/linen, cotton and polyester	A 24% reduction in HCAI, a 47% reduction in number of fever days and a 32.8% reduction in total number of days of antibiotic administration
Dykes (2015) ⁹⁰	CuO NPs/polyester	After 4 weeks, an increase in the mean net skin and biological elasticity of 31.4 and 20.7%, respectively, was observed
Gargiulo <i>et al.</i> (2012) ⁹¹	CuO NPs/polyester	Amelioration of tinea pedis
Baek <i>et al.</i> (2012) ⁹²	CuO NPs/polyester	Decrease of crow's feet was observed after 4 weeks
Borkow <i>et al.</i> (2009) ⁹³	CuO NPs/polyester	Reduction of facial wrinkles and crow's feet/fine lines after 2 weeks
Textiles modified by Ag compounds		
<i>In vitro</i> studies		
Rehan <i>et al.</i> (2017) ⁹⁴	Ag NPs/cotton	Blocks UV and inhibits <i>E. coli</i>
Xu <i>et al.</i> (2017) ⁹⁵	Ag NPs/cotton	Inhibits <i>S. aureus</i> and <i>E. coli</i> . Stable after 50 laundering cycles
Emam <i>et al.</i> (2015) ⁹⁶	Ag NPs/cotton	Inhibits <i>E. coli</i> and <i>S. aureus</i>
Li <i>et al.</i> (2017) ⁹⁷	Ag NPs/cotton	Inhibits <i>E. coli</i> and <i>S. aureus</i> , has improved UPF values
El-Rafie <i>et al.</i> (2014) ⁹⁸	Ag NPs/cotton	Inhibits <i>S. aureus</i> and <i>E. coli</i> after 20 washings
Zhang <i>et al.</i> (2013) ⁹⁹	Ag NPs/cotton	Inhibits <i>S. aureus</i> and <i>E. coli</i> after 50 washings
Gerba <i>et al.</i> (2016) ¹⁰⁰	Ag NPs/cotton	Inhibits salmonella, MRSA, <i>P. acnes</i> , <i>T. mentagrophytes</i> , Enterococcus, <i>C. difficile</i> and norovirus
Balakumaran <i>et al.</i> (2016) ¹⁰¹	Ag NPs/cotton	Inhibits <i>B. subtilis</i> , <i>S. aureus</i> , <i>K. pneumoniae</i> and <i>P. aeruginosa</i>
Dhiman <i>et al.</i> (2015) ¹⁰²	Ag NPs/cotton	Inhibits <i>S. aureus</i> and <i>E. coli</i>
Pulit-Prociak <i>et al.</i> (2016) ¹⁰³	Ag NPs/cotton	Inhibits <i>S. cerevisiae</i>
Shaheen <i>et al.</i> (2018) ¹⁰⁴	Ag NPs/cotton	Inhibits <i>S. aureus</i> , <i>E. coli</i> , <i>C. albicans</i> and fungi
Rodrigues <i>et al.</i> (2019) ¹⁰⁵	Ag NPs/cotton and polyester	Inhibits <i>S. aureus</i> , <i>E. coli</i> , <i>C. albicans</i> , <i>C. glabrata</i> and <i>C. parapsilosis</i>
Ali <i>et al.</i> (2011) ¹⁰⁶	Ag NPs/polyester	Inhibits <i>S. aureus</i>
Noor <i>et al.</i> (2019) ¹⁰⁷	Ag NPs/polyviscose	Inhibits <i>E. coli</i>
Mofidar <i>et al.</i> (2019) ¹⁰⁸	Ag NPs/polyacrylic acid fibers	Inhibits <i>C. albicans</i> and MRSA
Rehan <i>et al.</i> (2018) ¹⁰⁹	Ag/AgI NPs/viscose	Inhibits <i>E. coli</i> and <i>S. aureus</i> and has UV protection
Tremiliosi <i>et al.</i> (2020) ¹¹⁰	Ag NPs/polyester-cotton	Inhibits <i>S. aureus</i> , <i>E. coli</i> , <i>C. albicans</i> , SARS-CoV-2.
Ibănescu <i>et al.</i> (2014) ¹¹¹	Ag/ZnO NPs/cotton and cotton-polyester	Inhibits <i>S. aureus</i> and <i>M. luteus</i>
Shin <i>et al.</i> (2014) ¹¹²	Ag/Ag-SiO ₂ NPs/polyester	Inhibits <i>S. aureus</i> and <i>E. coli</i>
Nischala <i>et al.</i> (2010) ¹¹³	Ag-SiO ₂ /cotton	Inhibits <i>E. coli</i>
<i>In vivo</i> studies		
Juenger <i>et al.</i> (2006) ¹¹⁴	Padycare (polyamide, Ag NPs/lycra)	Reduced clinical severity of AE and pruritus within a wearing period of 2 weeks
Park <i>et al.</i> (2012) ⁴⁵	Skin Doctor (TiO ₂ -Ag NPs/algal cellulose)	Reduction in <i>S. aureus</i> colonization and decrease in TEWL
Araújo <i>et al.</i> (2013) ¹¹⁵	Skin to skin (cotton, Ag NPs/algal cellulose)	Decreases up to 70% of itching. Quality of sleep improved to about 65%.
Fluhr <i>et al.</i> (2010) ⁴⁷	Ag NPs/algal cellulose	Reduction in <i>S. aureus</i> colonization and improved TEWL was observed during the first 4 weeks of the study
Strour <i>et al.</i> (2019) ⁴¹	DermaSilk (AEGIS 5772/silk), Padycare (polyamide, Ag NPs/lycra), SkinProtect (Ag NPs/cotton and polyester), Binamed (modal, Ag NP/polyester, lycra), Platatex (Ag NPs/cotton and polyester), Pulmanova Bioactive (Ag NPs/cotton), Silver-Skin (AgNPs/cotton and polyester), Best4Body (Ag NPs/cotton), Schiesser (Ag NPs/cotton), Medima Antisept (Ag NPs/cotton and polyamide), Sansita (micromodal, lycra and Ag NPs/cellulose)	Textiles coated by Ag NPs delivered durable antimicrobial activity unaffected by laundering
Hoefler <i>et al.</i> (2011) ¹¹⁶	Ag NPs/polyester	No pathogenic germs occurred in the microflora of the subjects during 4 weeks

Table 1 Continued

Reference	Material	Effect
Daeschlein <i>et al.</i> (2010) ⁴⁶	Ag NPs/polyamide	Inhibited <i>S. aureus</i> and total bacterial colonization after 2 days of wearing without washing
Morand <i>et al.</i> (2019) ⁴⁸	Ag NPs/polyamide and elastane	Alleviated perineal folliculitis

ATIE, antibiotic treatment initiation events; HCAI, health care-associated infection; MDRO, multidrug-resistant organisms; MRSA, methicillin-resistant *Staphylococcus aureus*; NPs, nanoparticles; TEWL, transepidermal water loss.

recommendation for widespread mask-wearing, it is reasonable to hypothesize increased incidence of maskne. It is important that the international dermatology community is made aware of how prescribing patterns may potentially influence the development of antibiotic resistance worldwide.

Role of dermatologists

Dermatologists should be aware of changes in the skin microbiome because of widespread fabric mask-wearing and its influence on new and existing dermatological conditions. The antimicrobial functions of biofunctional textiles and the new social "norm" of widespread mask-wearing present therapeutic opportunities for treatment of microbiome dysbiosis in maskne and chronic skin disorders, while decreasing the risk of antibiotic resistance in the population.

Several dermatological factors may influence noncompliance to mask-wearing. Individual discomfort in the form of retained moisture, sensation of stickiness, and inconveniences experienced by the individual caused by difficulty in speaking or breathing may be related to the design and material of the mask. Sensitive skin patient populations may experience heightened sensations with frictional dermatitis. A poor understanding of infectious disease control methods may also be a contributory factor to noncompliance. Dermatological benefits of biofunctional textiles, such as UV protection, treatment of skin disease, and antiaging, can potentially be viewed as additional evidence-based incentives for widespread face mask wear,¹ besides reducing the occurrence of common complications such as maskne and flare-ups of existing dermatological conditions caused by face masks made of traditional textiles.

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