Introduction

Problem

Dandruff is the most common scalp condition that is often accompanied by itching and erythema [1]. The complex causes of dandruff include excess sebum secretion from the sebaceous glands, hormonal imbalance, and excessive proliferation of Malassezia species in the scalp. The viable numbers of these yeasts reportedly increase 1.5-2-fold in numbers when dandruff is present [2]. These species degrade triglycerides in the sebum to produce oleic acid, which is absorbed into the stratum corneum. After absorption, oleic acid causes an inflammatory response in keratinocytes, which disrupts homeostasis, leading to the erratic cleavage of keratinocytes, and ultimately to dandruff [3]. Underarm malodor is caused by the degradation of secreted milky odorless liquid consisting of electrolytes, steroids, proteins, and lipids from the apocrine glands onto the skin surface by the gram-positive bacteria Corynebacterium xerosis and C. jeikeium, which reside on the skin surface [4-7]. The bacterial biotransformation produces 3-methyl-3-sulfanylhexan-1-ol, 3-sulfanylhexan-1-ol, 3-methyl-3-hydroxy hexanoic acid, 5α-androst-16-en-3, isovaleric acid, and propionic acid [8-10], which are typical sources of malodor.

Typically, in non-severe cases of dandruff and underarm malodor, over-the-counter personal hygiene products are used. However, personal hygiene products used for the prevention and alleviation of symptoms are washed off from the body due to sweating and washing after use. Due to this reason, it is difficult to expect the persistence of antimicrobial effects and the products are used every day, which can irritate and sensitize the skin [11]. A novel approach is desirable.

Problem Solving Strategies

The scalp and armpit regions are typically replete with hair. Disulfide bonds in the hair keratin are reduced to cysteine by external environmental factors, including chemical treatment of hair and ultraviolet radiation [12]. Cysteine accounts for approximately 14% of all amino acids in hair keratin. Moreover, hair in the scalp and underarm is near skin that is colonized by microorganisms responsible for dandruff and underarm malodor. This suggests a strategy, in which the appropriate antimicrobial agents are immobilized onto cysteine thiol groups in hair keratin, where they would be readily available to kill the offending microorganisms. This strategy has merit, given that absorption, coating, and incorporation are often used to immobilize antimicrobial ingredients onto wool, hair, and fabrics. However, the antimicrobial effects often do not persist [13-15].

Strategy Tactics

In the present study, we immobilized an antimicrobial agent to cysteine thiol groups in hair keratin and evaluated the subsequent antimicrobial effects. In this approach, hair was first treated with thioglycolic acid, which served as a reducing agent to disrupt disulfide bonds in hair and reduce them to cysteine.
residues could then form covalent bonds with the antimicrobial agent. Next, through a thiol-ene reaction among [2-(acryloyloxy)ethyl] trimethylammonium chloride, an acrylate monomer containing QAC, and cysteine thiol groups, QAC was immobilized via covalent bonding onto the hair surface. QAC immobilization was confirmed through Fourier-transform infrared spectroscopy. The antimicrobial effects against six microorganisms that typically cause dandruff and underarm malodor were evaluated.

Result

The hair shaft covalently bonded of the QAC showed antibacterial activity against all tested bacteria. Although the antibacterial effect was slightly decreased after 5 washes, it was confirmed that the antibacterial effect still remained.

Conclusion

This report may provide for the first time the results of a study using human hair as a carrier for antimicrobial treatments. Based on these findings, we suggest that the method could potentially replace personal hygiene products, such as shampoos and antiperspirants, that act as antimicrobial agents for the prevention and alleviation of dandruff and underarm malodor. Furthermore, such products are for daily rather than for one-time usage. However, repetitive usage of these products may provide an accumulative effect. The findings may be useful for the alleviation of underarm malodor, since the hair there is in frequent contact with skin that harbors microorganisms causing such malodor.

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