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Increased water transport in PDMS silicone films by addition of excipients

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ABSTRACT

The development of new adhesive wound care products intended for an application over a prolonged time requires good water transporting properties of the adhesive for the maintenance of a suitable environment around the wound. The ability of polydimethylsiloxane (PDMS)-based silicone films to transport water has led to its use in skin pressure-sensitive adhesives and it would be advantageous to find ways for controlling or increasing water transport across PDMS films in order to be able to develop improved skin adhesives. In this study we present a way to increase water transport in such films by the addition of hydrophilic excipients. Three hydrophilic additives, highly water-soluble sucrose and the two superabsorbent polymers (SAP) Carbopol® and Pemulen™, were investigated. The effect of the excipients was characterized by water transport studies, swelling tests, scanning electron microscopy imaging and confocal microscopy. The cross-linked polymers, primarily Pemulen™, were efficient water transport enhancers, whereas sucrose did not show any effect. The effect of the additives seemed to correlate with their water binding capacity. For SAPs the formation of a percolating structure by swollen polymer was also suggested, which enhances water penetration by the higher volume fraction of areas with a higher diffusion constant (swollen SAP), leading to a faster transport through the entire film.

1. Introduction

Pressure-sensitive adhesives (PSAs) have been used in a range of medical applications such as wound coverings and closures or transdermal drug delivery systems. Silicone-based adhesives are one class of PSAs commonly used in wound dressings due to their good adhesive properties, moisture resistance, stability and a non-irritant and non-toxic nature [1]. An optimal wound dressing should have good adhesive properties; the adhesiveness has to be maintained over a longer time even though the skin surface properties might change, e.g. due to sweating or exudates from sloughy wounds, and the wound dressing should not cause any damage on the skin, neither during its usage nor during the removal [2]. Besides the adhesion properties, water transport across the adhesive is also important to obtain an appropriate moisture environment so that re-epithelialization is enhanced. When a patch is used over a prolonged time, occlusion can lead to changes in the skin pH and the bacterial flora as well as an impaired barrier function of the stratum corneum [3–5]. In addition, water accumulation can lead to an uncomfortable feeling on the skin, which may decrease patient compliance. Therefore, it is important to consider the ability of PSAs to transport water and other liquids from the skin to the environment, so that the degree of occlusion can be controlled.

Silicone is known to allow the permeation of gases and water vapor [6,7]. Silicone films with increased water transport but with remaining adhesive properties might be helpful in the development of new adhesive formulations with improved water permeability for use on skin over a prolonged time. The focus of this study was therefore on transport of water in polydimethylsiloxane (PDMS) films with the aim to increase water mass transport through such films by the addition of different hydrophilic additives.

The diffusive flow through a film or membrane can, for steady-state conditions, be written as:

$$J = -\frac{D_e A H}{h}(c_d - c_a) \tag{1}$$

where D_e is the effective diffusion coefficient in the film, A is the area across which diffusion occurs, H is the partition coefficient, h is the film thickness, and c_d and c_a are the concentrations on the donor and acceptor side of the film, respectively [8]. For a homogeneous system D_e could be replaced by the actual diffusion coefficient D, which for polymer solvent systems generally increases with increasing volume fraction of the solvent [9]. However, in heterogeneous systems or systems with solvent concentration variations within the film, there will be spatial variations of D. Furthermore, in systems containing different phases with different D, the structural

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