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REVIEW

Tear exchange and contact lenses: A review

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Abstract Tear exchange beneath a contact lens facilitates ongoing fluid replenishment between the ocular surface and the lens. This exchange is considerably lower during the wear of soft lenses compared with rigid lenses. As a result, the accumulation of tear film debris and metabolic by-products between the cornea and a soft contact lens increases, potentially leading to complications. Lens design innovations have been proposed, but no substantial improvement in soft lens tear exchange has been reported. Researchers have determined post-lens tear exchange using several methods, notably fluorophotometry. However, due to technological limitations, little remains known about tear hydrodynamics around the lens and, to-date, true tear exchange with contact lenses has not been shown. Further knowledge regarding tear exchange could be vital in aiding better contact lens design, with the prospect of alleviating certain adverse ocular responses.

This article reviews the literature to-date on the significance, implications and measurement of tear exchange with contact lenses.

PALABRAS CLAVE
Lentes de contacto;
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Película de lágrimas;
Fluoresceína;
Fluorofotometría

Intercambio de lágrima y lentes de contacto: revisión

Resumen El intercambio de lágrima bajo las lentes de contacto facilita la reposición continua de fluido entre la superficie ocular y las lentes. Dicho intercambio es considerablemente menor con el uso de lentes blandas en lugar de rígidas. Como resultado, se incrementa la acumulación de desechos de la película de lágrimas y los sub-productos metabólicos entre la córnea y las lentes de contacto blandas, lo que conlleva complicaciones potenciales. Se han propuesto innovaciones en el diseño de las lentes, pero no se ha reportado ninguna mejora sustancial en lo referente al intercambio de lágrima con las lentes de contacto blandas. Los investigadores han determinado el intercambio de lágrimas tras el uso de lentes utilizando diversos métodos,

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principalmente la fluorofotometría. Sin embargo, debido a las limitaciones técnicas, se conoce poco acerca de la hidrodinámica relacionada con las lentes y, hasta la fecha, no se ha mostrado un intercambio de lágrima substancial con lentes de contacto. El conocimiento adicional sobre el intercambio de lágrima podría resultar esencial para ayudar a diseñar lentes de contacto mejoradas, con la perspectiva de aliviar ciertas respuestas oculares adversas. Este artículo revisa la literatura hasta la fecha acerca de la importancia, implicaciones y medición del intercambio de lágrima con lentes de contacto.

Introduction

It has been estimated that there are approximately 140 million wearers of contact lenses (CL) worldwide.[1,2] Despite the introduction of many new lens materials and care systems, dryness and discomfort continue to be reported by some 30–50% of lens wearers, particularly at the end of the day.[3–7] As a result of this discomfort, 30–50% of wearers will at some point lapse from lens wear [8–10] and 25% of wearers will permanently cease contact lens wear.[10] Of greater concern is that more severe complications such as contact lens-induced microbial keratitis and inflammatory conditions have not decreased in the past decade.[11–16] Numerous factors are associated with contact lens discomfort[17–22] and inflammation.[2] One aspect of the lens–tear–cornea interaction that has received relatively little attention is tear exchange. Soft contact lens design and fitting have remained essentially unchanged since their introduction in the early 1970s and it has been suggested that improving tear exchange and ''flushing'' beneath lenses may reduce inflammatory events and could improve long-term wearing success.

In this review, we examine and discuss the current literature on tear exchange with contact lenses, including its significance, mechanism and the strategies proposed to improve both tear exchange and its measurement.

Role of tear exchange in contact lens wear

When a contact lens is placed on the eye, the lens divides the tear film into two layers, the outermost layer that overlies the lens, which is termed the pre-lens tear film (PrLTF), and the layer between the back surface of the lens and the cornea, which is referred to as the post-lens tear film (PoLTF).[23–25] The fluid circulation between the pre- and the post-lens tear film is commonly referred to as ''tear exchange'', with authors also using the terms ''tear turnover'', ''tear pumping'', ''tear flow'', ''tear flushing'' or ''tear mixing'' synonymously.[26–34] The importance of tear exchange behind a contact lens remains an ongoing debate. Historically, tear exchange has been ascribed the leading role in delivering oxygenated tears to the cornea behind non-permeable, polymethyl-methacrylate (PMMA) contact lens materials.[35,36] However, modern, highly oxygen transmissible silicone hydrogel (SiHy) lenses have virtually eliminated hypoxic complications, and the significance of tear exchange has been redefined. It is now considered essential that tear exchange occurs in an attempt to reduce post-lens debris, as metabolic byproducts that stagnate between the lens and cornea, particularly in extended (EW) and continuous wear (CW), can perhaps contribute to the onset of adverse events, by altering the epithelial barrier function.[37–39] Despite excellent oxygen permeability properties, reviews indicate that SiHy wearers still develop a number of adverse events when lenses are worn overnight.[2,40–45] These include inflammatory conditions, including contact lens peripheral ulcers, (CLPU)[46–50] contact lens-induced acute red eye (CLARE)[47,48,51] and infiltrative keratitis (IK).[43–45,47,48,51,52] Incidence for these events varies between 1% and 5% in CW SiHy wearers, with recurrence rates being as high as 10% for CLPU, 14% with IK and 29% for CLARE.[47] These rates are to be considered with caution, as up to 50% of CLPU and some IK cases have been found to be asymptomatic and thus these rates may underestimate the true rates. Corneal infiltrate incidence in CW users of a SiHy lens was 5.7%, 8.5% and 10.3% after one, two and three years of wear, respectively, as opposed to 1.6–4% in non-contact lens wearers.[53] The most sight threatening complication for contact lens wearers, microbial keratitis (MK), still affects 3–5 in 10,000 daily CL wearers, a number that has remained constant over the past 20 years.[54] A number of reports suggest that most of these conditions are not due to hypoxic stress, but rather due to the presence of bacterial exotoxins, which could lead to inflammatory complications if their removal is delayed due to tear stagnation beneath the lens.[40,48,55]

While not inflammatory in nature, ''mucin balls'' are a further complication observed with EW/CW of SiHy lenses.[56–61] These spherical, translucent, insoluble bodies, ranging in diameter from 10 to 100 μm, are composed of naturally occurring tear film mucins and form between the back surface of a contact lens and the cornea, being rigid enough to indent and leave an imprint on the epithelial surface (Fig. 1).[61] While their exact formation remains unclear,[57] several factors may contribute. The composition of tears changes during sleep, with a much reduced aqueous phase, resulting in more viscous tears.[62–66] The high lens modulus (stiffness) and low deposition rate of SiHy's, coupled with the sheer forces of the cornea-lens interaction may cause the mucin within the post-lens tear film to roll up into spheres.[61] Their occurrence is high in patients who sleep in lenses, with 60–100% of eyes exhibiting mucin balls after 1–3 weeks of CW.[46,67] The percentage of subjects who never used lubricating drops was up to three times higher in subjects with mucin balls than in those without mucin balls ($p = 0.0014$).[56] This suggests that artificially enhancing tear