From Dusk to Dawn: Contact Lenses in the Night Tear Proteome

Part 1: My Story

I saw the letter "E," big, black and bold. "Now read me line six," the nurse said, pointing to a row of blurry rectangles. I squinted and took my best educated guess, but the nurse frowned, scribbling a note on her clipboard. The second week of first grade, I had failed my first test.

The school vision test was the one (and usually only) exam I failed each year. It became somewhat of a routine, seeing the school nurse, squinting at the fuzzy shapes on the eye chart, finding myself in the optometrist's office a week later. The doctor would check my eyes, shake his head, and write out a prescription for new glasses. The new lenses gave me crystal-clear vision (along with a headache) for a couple of weeks. Then slowly but surely my vision would degrade, until at the next year's vision screening, the cycle would begin anew, only with thicker lenses and deeper frowns.

For a long time I simply accepted this as a fact of my life, that I would never see clearly in the swimming pool, always have to wear the biggest, most bulky lab goggles, and forever be forced to endure this downwards spiral of nearsightedness. Soft contact lenses helped a bit, but they soon became dry and irritating, and technically should not have been worn in the lab or swimming pool at all. I saw no light, not even a blurry one, at the end of this tunnel. Potential laser surgery was a long ways off, and if my eyes continued their nearsighted progression, even that option would carry great risk.

Two years ago, I stumbled upon something that would change my life. At a gathering of family friends, my mother noticed that one of her friend's daughters, who used to wear glasses, was now free of spectacles. The casual comment of "How do your contacts feel?" revealed that the girl was not, in fact, wearing any contacts. Not at the time, anyway – she had been fitted with overnight orthokeratology (ortho-k) contact lenses, a special type of rigid contact lens that is worn at night. During sleep these lenses reshape the cornea, and during the day the molded cornea effectively acts like a natural contact lens, eliminating the need for glasses or contacts during the day.

When my mother heard that these ortho-k lenses also help slow the progression of nearsightedness, a look of first disbelief, then hope, then determination came across her face. My brother jumped on board fairly quickly – he's somewhat of a daredevil, certainly not one to shy away from getting rid of his glasses. I, however, took some more convincing – hadn't my other eye doctors always warned me NEVER to sleep in my contacts? Yet this optometrist was not only allowing, but requiring me to sleep in these lenses every

night. At the continued urging of my family, I finally agreed to try out ortho-k lenses, but in the back of my mind, I never forgot this question.

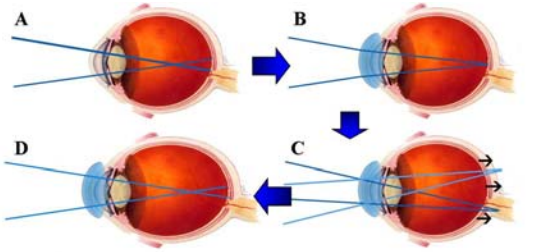
Through talking with my eye doctor and searching online, I found that a main reason for not wearing contact lenses at night is concern over protein deposition. Tears in our eyes naturally have proteins dissolved in them, many of which play antibacterial and other beneficial roles. However, these proteins also have a tendency to attach to contact lenses, and when they do, can cause a range of issues ranging from blurriness to irritation to infection. Clearly, protein deposition on contact lenses is a large concern, and the less protein adsorbed, the better.

I did some more research online and found that not all contact lenses are created equal when it comes to protein deposition. Most studies showed that soft lenses (such as those worn during the day) tend to attract more protein than hard lenses (such as those used in ortho-k). This seemed to answer the question of why I could wear these ortho-k lenses, but not my previous soft contacts, at night. As I was about to leave the page, however, I came across another article, this one saying that tears in the eye at night actually have a very different protein composition from those of the day. I looked back at the previous articles comparing hard and soft contacts, and found that all of them were indeed done during the day, none of them at night. There was a void here, one that this project begins to fill.

Part 2: The Science

About Overnight Orthokeratology

Orthokeratology, also known as “ortho-k” or simply “OK,” is an alternative method of treating nearsightedness. Some call the procedure corneal reshaping—patients wear a specially designed rigid gas permeable (hard) lens at night. This “reverse-geometry” lens has a unique curvature that molds the front of the eye, flattening the cornea. In the morning, patients remove the lens, and the reshaped cornea effectively acts like a natural contact lens, providing its own refractory power, giving patients clear daytime vision free from corrective eyewear.



▲Peripheral light focusing with daytime lenses, a proposed mechanism for myopia progression

Corneal reshaping has an additional benefit for young people—slowing or stopping the progression of myopia. Nearsightedness is caused by light rays focusing in front of the retina (A), producing a blurry image for distant objects. Traditional treatments (glasses or daytime contacts) refract central light to focus on the retina, producing a clear image (B). However, these lenses actually cause peripheral light rays (those entering at an angle) to focus behind the retina (C). The eye elongates toward this focal point (D), fueling a vicious cycle of increasing nearsightedness. Orthokeratology mitigates this effect by using the cornea’s natural focusing power to refract light, reducing peripheral defocus and slowing myopia progression.

Purpose

This project seeks to explore how proteins interact with overnight orthokeratology contact lenses in the nighttime tear proteome, and compare this to how proteins interact with more widespread silicone hydrogel (commonly known as “soft”) lenses under similar conditions. Little research has been done on contact lenses in nighttime eye conditions, which is possibly justified since most contacts are worn during the day. Orthokeratology, however, necessitates nighttime wear, and its potential benefits warrant an investigation into nighttime protein adsorption.

Hypothesis

Before experimentation, it was hypothesized that if silicone hydrogel and overnight orthokeratology contact lenses are placed in a simulated nighttime tear film, the silicone hydrogel lenses will adsorb more protein, and the orthokeratology lenses less. Existing research about protein interaction with contact lenses

indicates more adsorption to soft lenses and less to hard lenses. The reasoning behind these studies was that the soft lenses are more hydrophilic than the more hydrophobic hard lenses, and therefore should more strongly bind charged proteins. These studies were all done in the daytime tear proteome, but it was thought that lenses and proteins would exhibit similar behavior in this project.

Methods

A protein solution was created to mimic nighttime tears – two proteins, lysozyme and human serum albumin (HSA), were used. Lysozyme is abundant in both daytime and nighttime tears, while HSA is prevalent only at night. Contact lenses (3 soft and 3 ortho-k) were placed in flat lens cases and immersed in the tear solution for 12 hours to simulate overnight wear. Lenses were then removed from protein solution, dipped in saline to remove unbound protein, and placed in extraction buffer. Protein deposits were analyzed by reversed-phase high performance liquid chromatography.

Results

Figure 1: Protein Adsorption on Contact Lenses

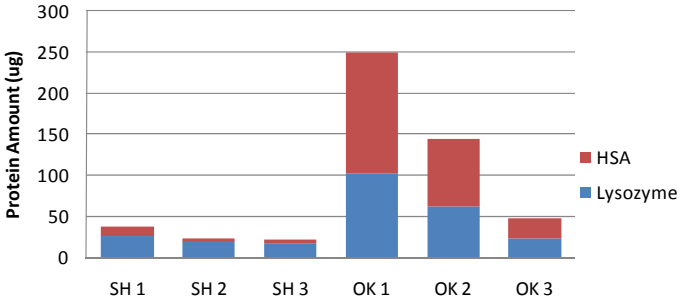


Figure 2: Relative Protein Contribution

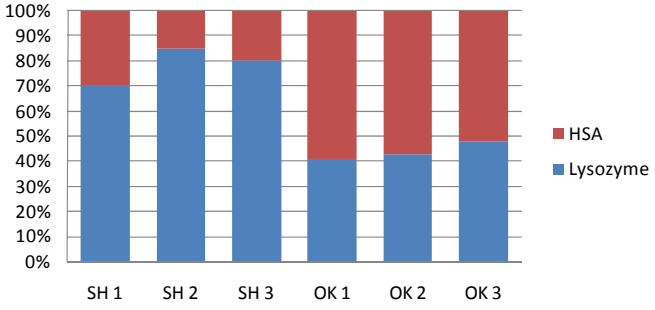


Figure 1 shows the amount of protein adsorbed on each of the six lenses, three of each type. The total length of the bar represents the total amount of protein detected, with the red and blue portions showing the contributions of HSA and lysozyme, respectively. Several interesting observations can be drawn from this graph. Looking at the overall lengths of bars, it is apparent that the silicone hydrogel lenses on the left yielded lower amounts of protein than the orthokeratology lenses on the right (contrary to the original hypothesis). Looking at the distribution of HSA and lysozyme in each sample yields more intriguing information. The ortho-k lenses on the right show slightly more red than blue (indicating a preference for HSA), while the SH bars on the left are almost exclusively blue (indicating a preference for lysozyme). Figure 2 extends each bar to 100% to better illustrate the relative contribution of each protein.

Even though the amount of total protein varied, as shown in Figure 1 (especially among the OK lenses) , the ratio of HSA to lysozyme remains remarkably similar within the three lenses of each group as shown in

Figure 2. The silicone hydrogels on the left consistently preferred lysozyme (blue), while the orthokeratology lenses on the right had more of a preference for HSA (red).

This provides a plausible explanation as to why the data does not support the hypothesis, and therefore differs from the results of previous studies. The soft silicone hydrogel lenses preferentially bind lysozyme, which is abundant during the day, while the hard ortho-k lenses bind more albumin, which is abundant only at night. Therefore during the day (as in other studies), when lysozyme is abundant and albumin very low in concentration, the soft lenses may very well bind more protein than hard. However, at night (as in this project) we see that the proteins specific to night tears interact quite readily with orthokeratology lenses.

Implications

This project begins to shed light on the little-explored area of contact lenses in the night tear proteome. Its results show that overnight orthokeratology lenses are not immune from protein adsorption; indeed their more hydrophobic nature may increase their susceptibility to nighttime tear protein interaction. For eye doctors and patients, this study highlights the importance of regular disinfection, along with the dangers of extended wear. Lenses must be regularly removed and carefully cleaned to control protein buildup. As long as a careful lens care regimen is followed, orthokeratology lenses are still an excellent choice – their potential for slowing or stopping the progression of nearsightedness has immense benefits for long-term eye health.

As for me, I have worn ortho-k lenses for two years now. The road has been far from smooth – I was already fairly nearsighted when I started wearing the lenses, and the doctors warned me from day one that I would not be an easy case. But we all persevered – me in driving to appointments, my optometrists in making adjustments, my family in patience, my tennis partner in putting up with my poor depth perception. Two years, dozens of appointments and many miles later, I finally have clear, lens-free vision. With the help ortho-k, I have rediscovered my love for swimming, and can once again wear whatever goggles in the lab I please. Perhaps most of all, my eyes have halted in their progression of nearsightedness, and I have not failed a vision test since.

My experience with ortho-k has not only given me literal vision, but also a vision for vision – I feel that my future lies in the field, and hope to improve the vision of others in the world. This fall I will be heading up to Harvard to further my interest in the biological sciences, with hopes of one day making larger contributions to vision and health. Thank you for your time, and feel free to contact me with any questions, comments or ideas! Thanks also to Professor Mazziotti and the University of Chicago for giving us young scientists this wonderful opportunity.