The Use of Contact Lenses in Swimming and Scuba Diving†

C. Hoelting*
D.J. Egan**
E.S. Bennett***

Abstract

The ametropic swimmer or scuba diver is at a disadvantage when engaging in these sports. This paper addresses some aspects of the problem, and offers some solutions as to the use of contact lenses: the effect of a wet environment on the physical properties of rigid and flexible materials, and how fitting characteristics may be affected; the pros and cons of both rigid and flexible contact lenses in swimming with and without goggles and masks; the professional person's advice in the above sporting activities when contact lenses are desired.

Abrégé

L'amétrope est à un désavantage lorsqu'il désire faire de la natation ou de la plongée sous marine. Ce travail s'adresse à quelques aspects du problème et offre des solutions pour leur usage dans ces sports: l'effet d'un environnement mouillé sur les propriétés physiques de matériaux rigide et flexible et les effets sur l'ajustage et la performance des lentilles; le pour et le contre des lentilles rigides et souples dans la natation et la plongée avec et sans masques ou lunettes protectrices (goggles); les recommandations du professionnel à ceux qui désirent utiliser des lentilles dans ces sports.

Introduction

Millions of Americans enjoy all types of water sports both recreationally and competitively. As in any athletic endeavor, vision plays a large role in determining performance and enjoyment. Those with a refractive error are at a distinct disadvantage. Unlike the emmetrope, they can't just put on a pair of goggles or a face mask and see when they get in the water.

Being able to see clearly can have profound effects if no more than being able to find the towel or locate friends when getting out of the water. In competitive swimming and diving, it is well known that being able to see clearly is a distinct advantage. Not only does one's depth perception improve, but also one's awareness of position and direction. They are very important when trying to shave off seconds or tenths of seconds from one's time.

What role can contact lenses play in water sports? This paper will attempt to determine what possibilities contact lenses hold, their uses, problems, precautions and limitations. Specifically, the use of contact lenses in swimming and scuba diving will be explored.

The Use of Contact Lenses in a Wet Environment

The first question to consider with regard to the use of contact lenses in water-related activities is: "What happens to the lens? Do any physical changes take place?" As with much of the discussion in this paper, the rigid contact lens can be discussed rather quickly. The rigid PMMA contact lens is essentially water-free and impermeable, so its parameters remain unchanged in wet environments.

The hydrogel contact lens, however, is very vulnerable to its surroundings, especially with any change in tonicity. It is well known that when a hydrogel contact lens is placed in a hypotonic solution it will imbibe water and flatten. One could then predict that the lens should become loose on the eye. Likewise, the wearing of a hydrogel contact lens in salt water, a hypertonic environment, should cause the lens to lose water and steepen in fit,

* Final Year Intern
** O.D., F.A.A.O., Assistant Professor of Optometry, Director of Clinics
*** O.D., M.S. Ed., F.A.A.O., Assistant Director of Contact Lens Clinic
School of Optometry
University of Missouri - St. Louis

†Reprinted from The Journal of the Missouri Optometric Association Second Quarter / 1983 issue. Reprinted by permission.

resulting in a tighter fitting lens.[1] In reality, the resulting fit in each case is just the opposite. The more hypotonic the environment the tighter the lens sticks to the cornea; the more hypertonic the looser the lens fits.

Why do the lenses stick on the cornea in hypotonic conditions? It would be easy to assume that the resulting hydrated lens is hypotonic with respect to the cornea and the resulting osmotic gradient causes water to be drawn from the lens into the cornea, resulting in a "pull" or sticking of the lens to the cornea. It has been reported that a sodium chloride content below 0.8 percent began to produce an adherence effect. This effect grew stronger with decreasing tonicities until complete adherence of the lens to the cornea occurred at 0.4 percent sodium chloride.[2] This would tend to correlate well with the osmotic gradient theory; that is, the cornea being hypertonic with respect to the lens, imbibes water from the lens. The cornea, being able to maintain a state of normal dehydration through its inherent physiological mechanisms, remains hypertonic and therefore the lens remains adhered to the cornea.

Conversely, it has been found in some patients that when they tear profusely the lenses also stick to the cornea. It is difficult to explain this finding as a result of a change in tonicity of the tears, since it is usually thought that the normal tear tonicity does not vary more than 0.1 percent from the 0.9 percent sodium chloride equivalent.[2]

In an experiment by Solomon, hydrogel lenses were equilibrated in concentrations ranging from 0 percent sodium chloride to 1.8 percent sodium chloride. The experiment attempted to imitate the effect of the lens on the cornea; that is, two materials of different tonicities coming into contact. All combinations of lenses failed to stick, to any degree, with one another.[3] As a result, consideration must be given to other possible factors including the following:

1) Surface factors of the hydrogel lens. Lenses manufactured with different surface electrical charges and surface viscosities, but having the exact parameters can act as differently as if base curves were changed by diopters.
2) Dimensional changes. The swelling of a lens may tighten the fit. The shrinking of the lens may loosen the fit.
3) Perhaps thinning or thickening the tear film between the lens and cornea is a factor.[3]

Whatever the reasons are for hydrogel lens sticking, it is known that altering the osmotic environment alters its ability to adhere to the cornea. A study measuring the amount of tensile force needed to pull a lens off the cornea under various salt concentrations showed that it didn't matter for the rigid lens. No matter what the salt concentration was, the amount of force necessary was extremely low.

However, the amount of force necessary to remove a hydrogel lens remained relatively high and constant until up to 0.9 percent sodium chloride, at which time the amount of force dropped and continued to fall until around 1.1 percent, at which time adhesion was extremely low and remained constant with increasing concentrations.[4]

Interestingly enough, however, in the same experiment the spontaneous loss of a lens at various salt concentrations was investigated. It was found that at no concentration was there any difference in hydrogel lens loss. Not a single hydrogel lens fell out of the eye despite frequent vigorous eye blinking and head movements. As could be expected though, all the rigid lenses fell out at all salt concentrations.

Swimming and Contact Lenses

Should or can one wear contact lenses while swimming? To answer this question the following need to be considered:
1) Is there a high risk of lens loss?
2) Can the lenses become damaged?
3) Are there any adverse effects on the eye or on vision?
4) Is there a safety factor for the wearer while swimming, and should any precautions be taken?[5]

Rigid contact lenses can be summed up quite briefly. The risk of lens loss is so high that their use in swimming is contraindicated. The loss frequency can be reduced if an oversized lens is used in combination with squinting by the swimmer. However, even with these precautions the rigid contact lens wearer should be instructed carefully as to the possibility of lens loss.[6]

It was discussed earlier as to why hydrogel contact lenses adhere to the cornea. Can the swimmer safely assume then that there is a low risk of hydrogel lens loss? Several studies have shown that in chlorinated pool conditions, hydrogel lenses showed signs of sticking to the cornea within one minute and were firmly adherent in three to four minutes. Once out of the water the lenses showed signs of loosening in five to ten minutes and the normal lag on blinking returned within fifteen to thirty minutes. The removal of the lens can be hastened by instilling normal saline solution, although a minimum of fifteen to twenty minutes is still necessary.[1,3,5,7]

The average hydrogel lens loss in all of the studies was 10-15 percent. The experiments were carried out under rigorous conditions. The swimmers were usually of competitive caliber. They were instructed to swim as much as possible with their eyes open, even to the point of diving into the water with both eyes open.[1,3,5,7,8] It can be safely assumed that an average swimmer does not generate nearly the force that the study participants would. Lens loss by the average swimmer would probably be less.

One might be able to expect the same degree of lens loss in conditions other than chlorinated pools. Although almost no studies have been done in conditions other than chlorinated pools, one experiment performed in fresh and sea water showed no hydrogel lens loss. In fact, the investigator claims that the lens adhered for a longer time after swimming in sea water than it did after fresh water or in a chlorinated pool.[9]

Although this low degree of lens loss is obviously an advantage, it can be the cause of serious injury. If a hydrogel lens is forcefully removed after swimming before it has had time to loosen, corneal epithelial denuding could take place.

Other adverse effects of swimming with hydrogel lenses have been studied. It is well known by anyone who swims in a chlorinated pool that one's eyes tend to burn after awhile. Competitive swimmers call this a "chlorine burn" which occurs in as early as fifteen minutes of swimming. "Chlorine burn" results from corneal edema and epithelial cell damage. The biomicroscopic picture of "chlorine burn" resembles the microcystic corneal edema and staining seen in an over-wearing syndrome of contact lenses.[10] In comparative studies the use of hydrogel lenses completely eliminated or greatly reduced the "chlorine burn" signs and symptoms. There was no loss in visual acuity and no characteristic stipple staining. The hydrogel lens appeared to actually be viewed as a protective device or shield.[3,5,10]

The hydrogel lens therefore, may eliminate many of the causes of discomfort while swimming in a pool. Obviously, "chlorine burn" is diminished. In addition, the bobbing of the swimmers heads in and out of the water gave them a better sense of everything around them. They could now see since their ametropia was corrected and there was no corneal edema.[3]

Although seemingly giving the eye some protection while swimming, is there any damage to the hydrogel lens? It has been suggested that chlorine may bind to the polymer of hydrogel lenses triggering an allergic or delayed response. Analyses of the lenses following a number of studies do not substantiate this. No damage to the lenses was found.[3,5,10]

What precautions, then, should the professional eyecare practitioner give his/her patients concerning swimming with contact lenses? First of all, rigid contact lenses have too high a loss risk. Hydrogel lenses can be worn without loss, provided unsalinated water is splashed or instilled into the eye while wearing the lenses. This should be done for at least one minute prior to entering the water. Hydrogel lenses should not be removed from the eye for at least thirty minutes after leaving the water. Normal saline can be placed into the eyes to facilitate lens removal.

Although it appears as though it is safe to wear hydrogel contact lenses while swimming, samples of chlorinated pool water periodically show low counts of staphylococci, streptococci, and pseudomonas aeruginosa. If a patient has a small corneal abrasion, such as from a tiny foreign body under the lens, then the contamination of the lens could theoretically result in a serious ocular infection. It is for this reason that one should consider not recommending the unqualified use of hydrogel lenses for swimming.[5]

Underwater Use of Contact Lenses

There are approximately two million Americans who have received scuba diving instruction, 500,000 of whom actively engage in sport diving.[11] The visual demands while diving are quite unique. Objects appear one-fourth closer, and one-third larger than they really are.[12] There is a loss of stereoacuity. Color changes occur at various depths.[13] Above all, there is a loss of visual acuity.

Corneal immersion in water effectively nullifies the cornea's refractive property, producing 42 diopters of hyperopia, giving an unaided visual acuity near 20/4,000.[14] Obviously, a face mask or goggles would provide the necessary air interface and negate this problem. However, the face mask and goggles provide their own problems. A person with good vision normally has a visual field of 200 degrees horizontally and about 130 degrees vertically. Since total reflection from a plano surface takes place at 48.5° a diver wearing a mask or goggles can only have a field of 97 degrees in either direction.[12,13] Wrap-around masks with glass side plates allow unrestricted lateral vision, but as images pass from the side to the front an "image jump" occurs.[13] Adding to these visual problems is the diver who has a refractive error. Obviously, this person could benefit greatly from wearing some sort of correction while diving.

Prescription bearing masks and goggles have been in use for some time. How would contact lenses provide any advantage over these? Prescription bearing masks have a problem of fogging and getting out of alignment. Also, when the mask is removed, as is often necessary on surfacing, so is the prescription, making it difficult to locate one's partner or boat. Contact lenses would not only relieve these problems, but also allow for more normal central vision and full peripheral vision if side plates are contained in the mask.[6,13]

An early attempt at using contact lenses with diving was the Skin Diver Contact Air Lens (SCAL). This was a prescription scleral lens design fitted in the normal way. However, after fitting has been completed, an air space is made by cementing a small plastic cell on the front surface of the lens. This in actuality is a tiny mask on the front of each eye. The diver doesn't wear a face mask and has a wide lateral field resulting in an unobstructed view of the surroundings. These soon came into disuse, however, as divers would contract very serious cases of conjunctivitis. Since tests in hyperbaric chambers failed to elicit this response, it was assumed that the prolonged eye exposure to the water was the cause.[12]

Are there any problems then in wearing contact lenses behind a mask or goggle? One study has shown that corneal epithelial edema can occur in divers wearing PMMA rigid contact lenses. Divers experience soreness of the eyes, halos and spectacular highlights, and decreased visual acuity. These results were not seen with hydrogel lenses. Upon decompression, bubbles formed behind the rigid contact lens. These bubbles occurred in the precorneal tear film secondary to an outgassing of nitrogen from the cornea and tear film, relative to decreasing pressure as ascent from a dive progresses. The PMMA lens material does not allow for direct gas permeation, and tear exchange via blinking is inadequate to remove the bubbles. This trapped gas disrupts tear exchange and therefore interferes with metabolic exchanges, resulting in central corneal edema. The clinical presentation mimics a rigid lens that is fitted too steep. None of the above findings were seen for the hydrogel lens. It was assumed that the gel lens allowed for passage of nitrogen at a sufficient rate to dissipate all of the gas.[16]

In summary, the rigid contact lens can cause discomfort, corneal injury and visual impairment. In addition, the possibility of corneal infection is present which is known to occur at a greater frequency when the integrity of the corneal epithelium is compromised.[16] Also, as was discussed previously, the rigid lens can be washed out and lost quite easily. It is for these reasons the rigid contact lens should be discouraged for diving. The hydrogel contact lens, however, has not been reported to cause any problems while diving. The same advice and precautions used for the swimmer should also be considered for the diver.

Conclusion

Special considerations have to be taken in using rigid and hydrogel contact lenses for swimming and scuba diving. In addition to the possibility of corneal edema upon decompression from a dive, the rigid lens wearer needs to be instructed on the distinct possibility of lens loss in a wet environment. The chance for loss is high enough that its use in water sports should be discouraged.

The hydrogel contact lens, on the other hand, behaves quite differently. In a hypotonic environment, the hydrogel lens adheres to the eye. The frequency of lens loss has been found to be quite low. The lens itself does not seem to undergo any damage, and in fact, may even provide a certain degree of protection to the eye, especially in a chlorinated pool.

The swimmer and diver react quite favorably to the use of the hydrogel contact lens. The advantages presented in this paper are reflected in the increased performance and level of enjoyment that are reported in the literature.

As long as attention is given to the special instructions and precautions that were outlined, the hydrogel contact lens may provide the swimmer and diver a unique and viable alternative. Surf's up.

References

1. Spinell, M.R., A clinical guide to soft contact lenses, Chilton Book Co., Radnor, Penn., 1979, pp. 179-180.
2. Mandell, R.B., Sticking of gel contact lenses, *The International Contact Lens Clinic*, 2 (1): 28-29, Spring, 1975.
3. Solomon, J., Swimming with soft lenses, *Southern J. of Optometry*, 19 (8): 13-18, August, 1977.
4. Lovund, P., Nilsson, S.E.G., and Oberg, P.A., The use of contact lenses in wet or damp environments, *Acta Ophthalmol.*, 58 (5): 794-803, 1980.
5. Stein, H.A. and Slatt, B.J., Swimming and soft contact lenses, *Contact Intra. Lens Med. J.*, 3 (3): 24-26, July/Sept., 1977.
6. Vinger, P.F., Ocular Sports Injuries, *International Ophthalmology Clinics*, 21 (4): 146-148, Winter, 1981.
7. Stein, H., Swimming with soft contact lenses, *Contact Lens Journal*, 10 (3): 10-12, Dec., 1976.
8. Solomon, J., Swimming with soft lenses, *Contact Lens Forum*, 2 (2): 13-14, Feb., 1977.
9. Williamson, D.E., Soft contact lenses and scuba diving, *The Ear, Nose and Throat Monthly*, 50 (1): 64-68, Jan., 1971.
10. Solomon, O.D., Hydrophilic lenses for swimming, *Contact Intra. Lens Med. J.*, 4 (3): 93-94, July/Sept., 1978.
11. Manual Undersea Science and Technology, Fiscal Year 1974 Report, National Oceanic and Atmospheric Administration, Rockville, Maryland, Government Printing Office, 1974, p. 8.
12. Swanson, K.V., Underwater vision, *Contact Lens Society of Amer. J.*, 5 (1): 20-22, April, 1971.
13. Naylor, D. and Fisher, B., Contacts under the sea, *Contact Lens Forum*, 5 (10): 15-19, Oct., 1980.
14. Gillilan, R.W., Vision and water sports, *J. Am. Opt. Assoc.*, 51 (7): 683-685, 1980.
15. Personal communication with Kennett V. Swanson, St. Louis, Mo.
16. Simon, D.R. and Bradley, M.E., Corneal edema in divers wearing hard contact lenses, *Amer. J. Ophthalmol.*, 85 (4): 462-464, 1978.