

SCLERAL LENS WEAR IN SCUBA AND DEEP-SEA DIVING

A look at the potential hazards and possible benefits of wearing scleral lenses while diving.

KAROLIEN ELVING-KOKKE, MOPTOM; PETER GERMONPRÉ, MD; & ESTHER-SIMONE VISSER, PHD

Scleral GP lenses are used increasingly worldwide,[1,2] and the use and safety of wearing this type of contact lens has been studied extensively.[3,4] However, how these lenses perform under extreme conditions (for example, while deep-sea diving) has not been investigated—even though a mini-scleral amphibious optics contact lens for diving without a mask has been recently developed.[5] However, some complications associated with diving while wearing contact lenses have been documented.

While diving, your body is subjected to changes in external pressure. This pressure increases during descent, causing air in body spaces to compress and inert gasses to accumulate in our tissues. If additional gas molecules are not supplied (e.g., by equalizing the ears, sinuses, and mask and by breathing from a compressed gas source to add air to the lungs), the pressure in the ears, mask, and lungs becomes negative. During ascent to the surface, the reverse process occurs, and these air spaces become pressurized due to the positive pressure produced as these gasses expand.

After deep-sea diving for a relatively long time, the gas molecules that emerge from the tissues can form bubbles in the blood and/or tissues, leading to decompression sickness. Wearers of GP contact lenses, including wearers of scleral lenses, occasionally develop uncomfortable eyes, painful eyes, and/or blurred vision after diving. These symptoms likely result from gas bubbles (likely nitrogen gas) forming between the cornea and contact lens due to gas escaping from the cornea and the tear film upon ascent.[6,7] This complication can usually be prevented by performing a carefully regulated ascent, which allows any accumulated gasses to disperse harmlessly.[6]

In addition, wearers of GP lenses can experience blurred vision after diving due to physical displacement of the lens during diving or a lens that fits too tightly after diving.[6,7]

Wearing a contact lens reduces oxygen transmissibility to the eye. How oxygen permeates the scleral lens during a dive has not been investigated. An average dive lasts 45 minutes. During the dive, the inside of the dive mask retains near-normal oxygen concentrations due to air expired through the nose. Brown and Siegel[7] calculated that during a 45-minute dive, the mask contains sufficient oxygen (3.200µl) to meet the cornea's requirements.

Finally, wearers of contact lenses have an increased risk of developing microbial keratitis, particularly when wearing their lenses underwater,[8,9] although this risk is higher among wearers of soft contact lenses compared to wearers of GP contact lenses.[10,11] Patients who have irregular astigmatism have few lens options available and typically must wear rigid contact lenses to maintain clear vision.

Practical experience suggests that scleral lenses may be compatible with diving. However, this is based on anecdotal evidence from individual cases. Thus, further insight is needed regarding the consequences associated with wearing scleral lenses while diving, thereby providing more concrete knowledge with respect to the safety of wearing scleral lenses under these conditions.

QUESTIONNAIRE

To document the experiences of scleral lens wearers while deep-sea diving, we took extensive case histories of five of our patients who were both scuba divers and scleral lens wearers.

The indications for scleral lens use among these patients were keratoconus (two patients), high refractive

error (two patients), and post-penetrating keratoplasty (one patient). The characteristics of these five patients are summarized in Table 1.

All five patients in this case series wore non-fenestrated scleral lenses, and all lenses had either optimal or acceptable fitting characteristics per the Visser Scleral Lens Classification System.[4]

SIMILARITIES AND DIFFERENCES

Over a period ranging from 5 months to 10 years, the five divers performed a total of 1,785 dives while wearing scleral lenses. All of the dives were performed within safe decompression limits (i.e., with a low risk of decompression bubbles forming), and four of the five patients performed their dives in relatively colder (Dutch) waters. The average dive depth was ≤ 20 meters, and dive time averaged 40 to 60 minutes.

All five of the patients applied their scleral lenses at least 60 minutes before the dive and waited > 60 minutes after the dive before removing their lenses. When multiple dives were performed, the lenses were never removed between dives.

When removing their lenses, two of the patients reported that they always experienced increased tightness; a third patient reported that lens tightness was experienced occasionally. Two of the five divers reported that they occasionally cleaned their lenses after diving and then reapplied the lenses using saline. The other three never cleaned their lenses after diving. While clearing their mask, two of the patients always closed their eyes, two patients occasionally closed their eyes, and one patient never did.

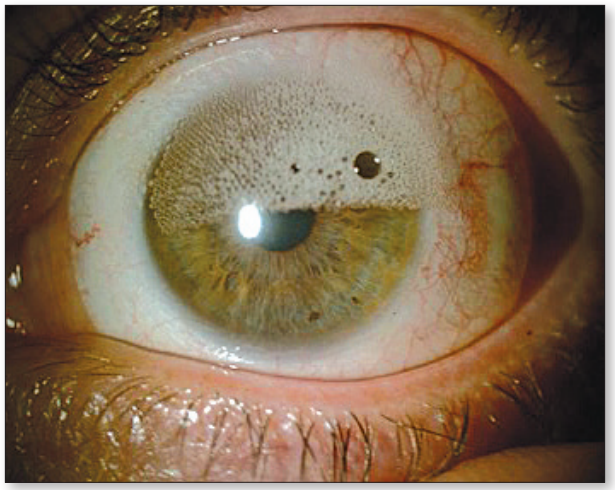

Figure 1. An example of "frothing" caused by air bubbles trapped beneath a large-diameter scleral lens.

After diving, two patients reported that their eyes occasionally appeared more red. Two patients reported occasional cloudiness during and after diving; one of those patients occasionally experienced reduced visual clarity after diving. Two of the five patients reported that they never experienced redness, cloudiness, or reduced clarity. Finally, none of the five patients reported experiencing any medical ophthalmic complications, including eye infection, while diving with their scleral lens.

WHAT WE LEARNED

Scleral lenses can have a "sealing" effect against the surface of the eye. When the lens' landing zone is fitted in alignment with the anterior ocular surface and is not too loose, air bubbles cannot enter, and the lens is less likely to become displaced or to fall out of the eye.[3,4] Figure 1 shows an example of air bubbles trapped beneath a scleral lens.

This is consistent with a report by Schwiegerling et al,[5] who developed a specialized mini-scleral lens for amphibious use. Importantly, this lens was not dislodged or displaced while diving, even when a mask was not worn. However, because the shape of the sclera is usually asymmetrical, a toric back-surface scleral lens often provides an improved fit, is more comfortable, and offers longer wearing time.[3,12,13]

When diving, the lens can be lost only if water enters the mask (for example, while clearing the mask or if wearing a poorly fitting mask). Using a well-fitting mask and narrowing the palpebral fissure (or closing the eyes) when clearing the mask can reduce the risk of losing a lens. Interestingly, however, only two of our patients reported that they always closed their eyes when clearing their mask. While taking the case histories, we did not ask whether the scleral lenses were lost or displaced during a dive, but this would be an interesting question to ask of future patients.

Three of the five patients reported that they found it more difficult to remove their scleral lenses after a dive due to a tighter fit of the lenses on the eye. Thus, scleral lens wearers should pay special attention when removing their lenses. In cases of increased lens tightness, the seal can usually be released by lifting the lens

In theory, a GP scleral lens can protect the eye from "mask squeeze" during a dive.

TABLE 1

CHARACTERISTICS OF THE FIVE PATIENTS IN THE CASE SERIES

PATIENT NUMBER	1	2	3	4	5
Ophthalmic condition	High astigmatism > 4.00D	Keratoconus	High myopia > 10.00D	Penetrating keratoplasty	Keratoconus
Scleral lens type*	Mini	Full	Full	Full	Mini
Scleral lens material	OD Menicon Z, OS GP 100	Boston XO_2	Boston XO_2	Menicon Z	Boston XO_2
Number of years as a scleral lens wearer	4	5	> 10	2.6	1
Total number of dives with scleral lenses	25	550	1,100	100	10

* Based on nomenclature used by the Scleral Lens Education Society.

edge; alternatively, the lens can be moved around with a plunger placed near the lens edge after instilling rewetting drops.

When diving while wearing a scleral lens, it is important to ensure that the lens is applied correctly, with no air bubbles trapped beneath the lens.

All of our patients whom we examined for this case series applied their scleral lenses at least 60 minutes before diving. Although a minimum scleral lens settling time has not been established prior to diving, a conservative minimum estimate is 30 minutes, which is based on the settling time used in practice when assessing a scleral lens.

In theory, a scleral lens can help protect the eye from "mask squeeze" during a dive. With mask squeeze, the air inside the mask does not properly equalize during descent; this causes unequal pressure between the air inside the mask and the intravascular pressure in the facial blood vessels, resulting in a condition known as facial barotrauma.[6] Historically, patients who have keratoconus are advised not to dive due to the increased risk of mask squeeze on the cornea. In this respect, wearing a scleral lens may—at least in principle—protect the cornea from rupture due mask squeeze by providing extra support. Nevertheless, none of our patients, including the two who had keratoconus, reported any ophthalmic problems related to their scleral lens wear.

No eye infections were reported by any of our patients, even though the scleral lenses were often not cleaned, either after diving or between dives; moreover, none of the divers reported any visible discharge on the scleral lens surface. However, to minimize the risk of infection, we advise our patients to remove, thoroughly clean, and reapply their scleral lenses after each dive, if conditions allow.

The average dive time of our patients was 40 to 60 minutes. Two of the five patients—whose dives lasted 40 and 60 minutes, respectively—complained of occasional increased lens cloudiness during and after diving. One keratoconus patient occasionally experienced reduced clarity after diving; this patient also reported occasional cloudiness, but no redness. Two patients reported occasional increased redness after diving. Despite these findings, whether the cloudiness, reduced clarity, and increased redness are a sign of oxygen depletion or another cause is currently unknown and should be investigated further.

> Remove, thoroughly clean, and reapply scleral lenses after each dive, if possible.

CONCLUSION

In summary, wearing GP scleral lenses while diving did not produce serious complications in our patients. Given the benefits of optimal visual correction and potential protection from pressure-related trauma (e.g., mask squeeze), continuing to wear their scleral lenses may be the safest option for these patients should they wish to dive. Nevertheless, additional research regarding scuba and deep-sea diving while wearing scleral lenses is needed to fully determine the entire range of risks and

Continued on p.49

Continued from **p.43**

benefits associated with wearing a scleral lens. In this respect, research is currently underway to evaluate scleral lens wear among the European diving community. This research will likely provide valuable insight into the subjective and objective experiences of patients who wear a scleral lens while diving. **CLS**

If you have patients who also scuba or deep-sea dive with scleral lenses, they would be able to add to our knowledge base by completing our questionnaire. To obtain information, a link to the questionnaire, and an informed consent form, contact us at KEG@visser-contactlenzen.nl, or visit the Divers Alert Network Europe research webpage at www.daneurope.org/web/guest/medical-research.

Karolien Elving-Kokke is an eyecare practitioner at several academic hospitals and is a member of the Visser scleral lens research and development team.

Dr. Germonpré graduated from medical school at the University of Ghent, Belgium. He also received his postgraduate certifications in hyperbaric and subaquatic medicine, emergency medicine, aviation medicine and sports medicine. Dr. Germonpré is medical director of the Centre for Hyperbaric Oxygen Therapy of the Belgian Military Hospital, Brussels. He is a past president of the European Underwater and Baromedical Society.

Esther-Simone Visser is an eyecare practitioner at several academic hospitals and head of the Visser scleral lens research and development team.

REFERENCES

1. van der Worp E, Bornman D, Ferreira DL, Faria-Ribeiro M, Garcia-Porta N, González-Meijome JM. Modern scleral contact lenses: A review. Cont Lens Anterior Eye. 2014 Aug;37:240-250.
2. Schornack MM. Scleral Lenses: A Literature Review. Eye Contact Lens. 2015 Jan;41:3-11.
3. van der Worp E. A guide to scleral lens fitting (2nd edition). Pacific University. 2015 Apr 23. Available at http://commons.pacificu.edu/mono/10/. Accessed on Sept. 18, 2017.
4. Visser ES. Objective and subjective performances of scleral lenses and new advances in scleral lens technologies. PhD Thesis, Utrecht University. 2015.
5. Schwiegerling J, Legerton JA, Chou B, Joyce RJ, Meyers W. Improving Underwater Vision: Part 2. Contact Lens Spectrum. 2013 Jan;28:40-44.
6. Divers Alert Network Europe (DAN Europe). www.daneurope.org.
7. Brown MS, Siegel IM. Cornea-contact lens interaction in the aquatic environment. CLAO J. 1997;23:237-242.
8. Stapleton F, Keay L, Edwards K, Holden B. The epidemiology of microbial keratitis in silicone hydrogel contact lens wearers. Eye Contact Lens. 2013 Jan;39:79-85.
9. Lindsay RG, Watters G, Johnson R, Ormonde SE. Snibson GR. Acanthamoeba keratitis and contact lens wear. Clin Exp Optom. 2007 Sep;90:351-360.
10. Stapleton F, Dart JK, Minassian D. Risk factors with contact lens related suppurative keratitis. CLAO J. 1993 Oct;19:204-210.
11. Poggio EC, Glynn RJ, Schein OD, et al. The incidence of ulcerative keratitis among users of daily-wear and extended-wear soft contact lenses. N Engl J Med. 1989 Sep;321(12):779-783.
12. Visser ES, Visser R, van Lier HJ, Otten HM. Modern scleral lenses part I: Clinical features. Eye Contact Lens. 2007 Jan;33:13-20.
13. Visser ES, Visser R, van Lier HJ, Otten HM. Modern scleral lenses part II: Patient satisfaction. Eye Contact Lens. 2007 Jan;33:21-25.