The Oxygen Transmissibility Profile of Siloxane Hydrogel Contact Lenses

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Abstract

New siloxane hydrogel contact lenses have enabled considerable leaps in the oxygen transmission capabilities of soft contact lenses. However, the numbers cited for oxygen transmissibility are calculated from the central thickness of a –3.00D lens, which gives the highest number. This does not take into consideration the transmissibility across the rest of the lens, which is dependent on its design.

Silicone hydrogel lenses, and for comparison, a widely used ordinary hydrogel lens, were sectioned and the thickness measured over the diameter of the lenses using a high resolution microscopic measurement technique previously described[1]. The thicknesses were used to profile the oxygen transmissibility perpendicular to the posteriour surface of the lenses across a section of the lens, and this is presented graphically. The mean of these values, based on harmonic mean lens thickness[2] and the manufacturers' cited Dk, were 139.1, 74.8, and 22.2. x 10^{-9} barrers/cm for the two lenses tested and an ordinary soft lens control respectively. The maximum transmissibility at the thinnest part of the lens was 191.8, 101.5, and 32.7, x 10^{-9} barrers/cm respectively.

Oxygen transmission with the new siloxane hydrogel lenses have been increased by a maximum factor of approximately six times over ordinary hydrogel lenses for both the central and mean values, making it possible to satisfy even the most stringent estimates of the corneal oxygen requirements for contact lenses during sleep.

Introduction

Harvitt and Bonanno have proposed a contact lens Dk/ t of 125 barrers/cm as a requirement to avoid anoxia in the cornea during sleep[3]. This is a higher requirement than that proposed by Holden and Mertz[4], which stipulated a value of 87 x 10^{-9} to avoid corneal swelling.

Contact lenses, by nature of having an optical power, have a variable thickness across their diameters. As the thickness has a bearing on other factors such as handling, comfort and durability of the lenses, the control of thickness in the lens centre, mid- and outer-periphery is an important aspect of lens design. The design of a lens will govern the oxygen transmissibility (Dk/t), which varies inversely with lens thickness (t), at each point across the lens section.

This study profiles the thickness of two siloxane hydrogel lenses and an ordinary soft contact lens, to evaluate their thickness and oxygen transmissibility profiles across the whole lens section.

Materials & methods

Two –3.00D lenses each, made from the three materials (Table 1), were sectioned across the centre using two parallel razorblades, and their thicknesses measured using a projection measuring microscope. The methods for validating the microscope against an ISO standard measurement method and of measuring the lenses have been described in detail previously[1]. The details of the tested lenses are in Table 2. Measurements were taken perpendicular to the back surface at 0.1mm intervals from edge to edge.

Table 1: Lens Material Details

Material	Type	Water content	Nominal Dk*
Lotrafilcon A	Fluoro-siloxane hydrogel	24%	140 x 10^{-11}
Balafilcon A	siloxane hydrogel	36%	99 x 10^{-11}
Etafilcon A	hydrogel	58%	28 x 10^{-11}

* Manufacturers' claimed values

Table 2: Contact Lens Details

Material	Parameters BC / Ø / power	Lot #
Lotrafilcon A	8.6 / 14.0 / -3.00D	9171003
Balafilcon A	8.6 / 14.0 / -3.00D	R88000501
Etafilcon A	8.8 / 14.0 / -3.00D	333107

As each lens gave two readings at the same distance from the centre (one on either side of the centre of the section), the four reading from each pair of lenses were averaged to give a half-diameter thickness profile for each lens type.

From the thickness readings, and the manufacturers stated Dk (Table 1), the Dk/t for each 1mm separation of the section was calculated and plotted to give a Dk/t profile corresponding to the thickness profile of the lenses. The harmonic mean thickness and its equivalent Dk/t for each lens was also calculated.

The Dk/t profiles and mean Dk/t, based on the harmonic mean thicknesses are shown in Figure 2, and the maximum, minimum and mean Dk/t based on harmonic mean thickness are shown in Table 3.

Table 3: Dk/t values

	Dk/t (x 10^{-9} barrers/cm)		
	Maximum	Minimum	Mean*
Lotrafilcon A	191.9	101.1	139.1
Balafilcon A	101.5	51.3	74.8
Etafilcon A	32.7	14.6	22.2

* Calculated using measured harmonic mean thickness.

Results

The thickness profiles and harmonic mean thicknesses of the lenses are shown in Figure 1. The left hand side of the graph in each case corresponds to the centre of the lens, and the right hand side the edge of the lens. The axes of the three graphs are the same to facilitate comparison.

Figure 1: Lens thickness profiles

Harmonic Mean Thicknesses
Lotrafilcon A lens – 0.101mm
Balafilcon A lens – 0.132mm
Etafilcon A lens – 0.126mm

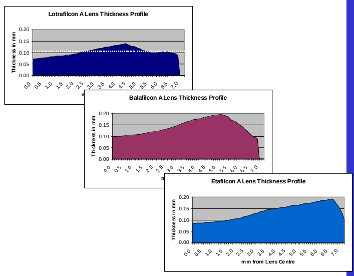
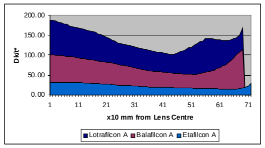


Figure 2: Dk/t profiles



* x 10^{-11} barrers/cm, # HMT = harmonic mean lens thickness

Discussion

The Dk/t profiles of the three lenses show that, centrally, only the two siloxane hydrogel lenses surpasseed the Holden and Mertz criterion of a Dk/t of 87 x 10^{-9} to avoid corneal swelling. Only lotrafilcon A lens exceeded the Harvitt and Bonanno criterion of a Dk/t of 125 x 10^{-9} to avoid corneal anoxia during sleep. When the thickness over the whole lens was taken into consideration, only one lens wholly exceeded the Holden and Mertz criterion, and none exceeded the Harvitt & Bonanno criterion.

When the harmonic mean thickness of the lenses was used to calculate Dk/t, the lotrafilcon A lens exceeded both criteria for avoiding anoxia, while neither of the other two lenses did. This can be attributed partly to the higher Dk of the lens material, but also to the lens design, where it is evident from the thickness profiles that efforts have been made to thin the mid-periphery.

It should be possible through further design modification to improve the oxygen transmission for such lenses, whilst still maintaining a good balance with handling, durability and comfort.

Conclusion

Thickness sections of lenses make it possible to determine oxygen transmission across the whole lens surface, providing more qualititative information on their oxygen transmission characteristics than simply citing the central Dk/t for a –3.00D lens. In this instance it can be seen that oxygen transmissibility should arguably be considerably higher than the central Dk/t normally cited to satisfy both old and new criteria for corneal oxygen requirements during sleep.

References

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