

# The Corneal Contact Lens and Aqueous Humor Hypoxia in Cats

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**The cornea normally receives its oxygen from both the atmosphere and the aqueous humor. When a thick polymethylmethacrylate contact lens is placed on the cat cornea, access of atmospheric oxygen to the cornea is restricted, and the outer part of the cornea becomes hypoxic. This results in an increase in the oxygen flux from the aqueous humor into the cornea, and the oxygen tension in the aqueous humor decreases, as is demonstrated in this study. This increased oxygen flux from the aqueous into the cornea tends to alleviate the hypoxia caused by a corneal contact lens. Thus, the cornea can tolerate a thicker contact lens with less hypoxia than would be expected if only the oxygen supply from the atmosphere were considered. Invest Ophthalmol Vis Sci 24:1052-1054, 1983**

Normally the corneal epithelium is oxygenated by the atmosphere. A corneal contact lens affects the oxygenation of the cornea by reducing the oxygen inflow from the atmosphere.<sup>1</sup> This can cause hypoxia of the cornea resulting in corneal edema.<sup>2</sup> However, in the case of hypoxia of the corneal epithelium and outer layers of the corneal stroma, additional oxygen will be extracted from the aqueous humor and its oxygen level will drop. The corneal endothelium receives its oxygen from the aqueous humor, and may itself become hypoxic when the anterior chamber oxygen tension decreases.<sup>3-5</sup>

This study shows changes in the oxygen tension of the anterior chamber aqueous humor of cats, during the use of an immobile, thick polymethylmethacrylate corneal contact lens.

The anatomical difference between the human and cat eyes as well as the design of the contact lens have to be kept in mind when the results of this study are considered.

## Materials and Methods

Six domestic cats were anesthetized with intramuscular ketamine HCl 20 to 30 mg/kg and intravenous pentobarbital sodium 30 to 50 mg/kg. The

cats were incubated and ventilated artificially on room air (respirator model, 661 Harvard Apparatus Inc., MA). CO<sub>2</sub> tension in expired air was monitored (CO<sub>2</sub> analyzer, Godart Statham NV, Holland) and maintained at 3.5 to 4.5%. Arterial blood pressure was measured through a cannula in the femoral artery connected to a saline column manometer. Arterial blood oxygen and CO<sub>2</sub> tension were measured (pH blood gas analyzer 213, temperature controller 329, Instrumental Laboratories, MA). Rectal temperature was measured with a mercury thermometer and maintained close to 37 C (range 35-37 C) with the help of a heating pad. The arterial blood pressure was 124 mmHg on the average (range 93-144 mmHg) arterial PO<sub>2</sub> was 105 mmHg on the average, (range 94-119 mmHg), and CO<sub>2</sub> in expired air was 3.9% on the average (range 3.7-4.2%).

In three cats, intraocular pressure was measured intermittently with a cannula through the cornea connected to a saline column manometer. The manometer tube was closed throughout most of these experiments and only opened intermittently with care taken not to allow fluid exchange between the saline line and the eye. In the other half of the cases, intraocular pressure was measured with an indentation tonometer (Schitz), to make sure that fluid exchange between the manometer and the eye had not affected the measurements.

The oxygen sensor consisted of a 110  $\mu$ m, 70% platinum-30% iridium bare tip electrode inside a 20-gauge steel needle. This electrode consumes oxygen at the rate of a few picoliters/min when in the anterior chamber, and the oxygen consumption of the electrode has an insignificant effect on the oxygen tension in the anterior chamber.<sup>6</sup> It is connected to a Chemical Microsensor 1201 (Transidyne General Corpo-

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ration, MI) and a Ag-AgCl reference electrode (Reference Electrode 1251, Transidyne General Corporation) that is put under the contralateral eyelid. The electrode current was found to be independent of the voltage between the anode and the oxygen cathode around 750 mV. At this polarizing voltage, the current-oxygen tension relationship was linear. The system was calibrated in 20.0%, 5.0% and 0.0% oxygen (N<sub>2</sub> to balance) in saline at 37 C (Transidyne General Calibration Cell 1251) before and after each experiment. Oxygen tension (current) measurements were recorded continuously on a chart recorder (Brush Electronics).

The corneal contact lens was made of polymethylmethacrylate. It had a flat anterior surface and a posterior surface curved to fit the cat's cornea (radius of curvature 7.7 mm). The lens diameter was 13.6 mm, the central thickness, 1.45 mm, and the edge thickness, 4.5 mm. The lens was fitted on the cornea with hydroxypropyl methylcellulose (Goniosol®, Smith, Miller, Patch, PR) between the contact lens and the cornea. The contact lens covered approximately 80% of the corneal surface, and did not touch the limbus.

A lateral canthotomy was performed and holding sutures placed in the conjunctiva. A 20-gauge cannula was inserted through the cornea, and the oxygen electrode was introduced through the cannula into the anterior chamber of the eye. The entrance point was watertight, and slight or no leakage occurred at the time of insertion. The tip of the electrode was placed in the center of the anterior chamber. When a steady oxygen tension reading was reached in the anterior chamber, the normal PO<sub>2</sub> was recorded for approximately 30 min. Then the flat-faced corneal contact lens was placed on the cornea for 1 hr or more, and the oxygen tension recorded. Then the contact lens was removed and the normal PO<sub>2</sub> was recorded for at least 1 hr. This procedure was repeated several times in each eye totalling 11 measurements in all.

### Results

All the eyes investigated showed a marked decrease of the oxygen tension in the anterior chamber when the contact lens was put on the cornea (Fig. 1). The oxygen tension level always rose again when the contact lens was removed (Fig. 2). The mean PO<sub>2</sub> in the anterior chamber aqueous was  $32 \pm 7$  mmHg without a contact lens on the cornea. The mean decrease in oxygen tension in the anterior chamber after 1 hr of contact lens wear as shown in Figure 1 was  $13 \pm 8$  mmHg (11 measurements, significant difference,  $P < 0.0005$ , Student's t-test). Although the intraocular pressures were variable (average 13 mmHg, range 4–

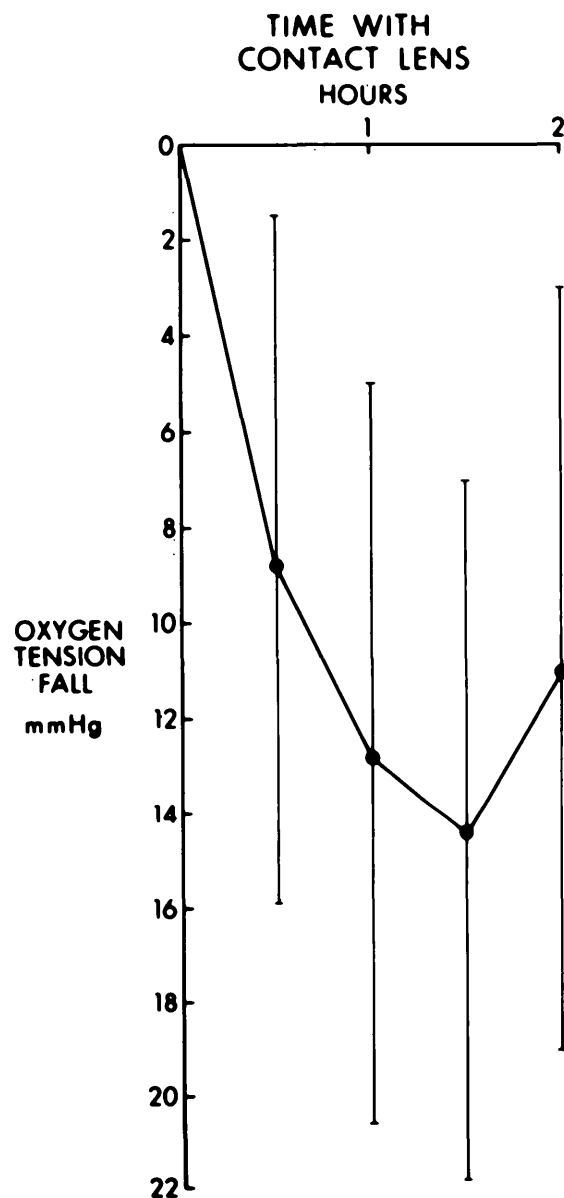


Fig. 1. Changes in oxygen tension in the anterior chamber. The effect of a corneal contact lens on the oxygen tension of the anterior chamber of a normal cat eye. This graph demonstrates how the oxygen tension in the anterior chamber decreases significantly after a contact lens has been placed on the cornea. The data is from 11 experiments in six cats, and mean and standard deviations are shown at 30-min intervals. The placement of a thick contact lens on the cornea always resulted in a sizable drop in the oxygen tension of the anterior chamber.

27 mmHg), the intraocular pressure was minimally affected (less than 5%) by the presence of the contact lens on the cornea.

### Discussion

Our data demonstrate conclusively that an immobile, thick, polymethylmethacrylate corneal contact lens with low oxygen permeability can affect the oxygen tension in the aqueous humor of the cat. An

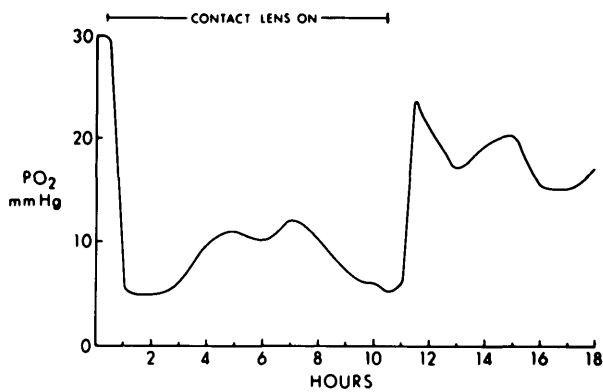


Fig. 2. Effects of extended duration use of a contact lens on the oxygen tension measurements in the anterior chamber of a normal cat eye. This graph shows a single experiment in which a thick contact lens was placed on the cornea. The oxygen tension in the anterior chamber subsequently decreased. When the corneal contact lens was removed 10 hrs later, the oxygen tension in the anterior chamber rose almost to the previous level.

impermeable contact lens induces a hypoxic state of the outer cornea.<sup>1</sup> When the corneal oxygen tension is decreased below its normal level, there is an increased oxygen flux from the aqueous humor into the cornea, which results in a decreased oxygen tension in the aqueous humor.

Friedenwald and Pierce<sup>7</sup> found a contact glass placed on the cornea of dogs had little effect on the oxygen tension in the anterior chamber although it did raise the CO<sub>2</sub> tension. However, their method did not allow the continuous measurement of the oxygen tension in the eye with the contact glass on and off. Conversely, McCulloch and Fielding<sup>8</sup> found corneal contact lenses to have no effect on the carbon dioxide tension in the anterior chambers of rabbits.

Barr and Silver<sup>9</sup> investigated the effect of changes in corneal environment on the oxygen tension in anterior chambers. A hard contact lens on the corneas of the rabbits caused the oxygen tension in the anterior chamber to drop, and the removal of the lens caused it to rise again. Their experiments were short, less than 1/2 hr, and they did not report whether the anterior chamber hypoxia was transient or long lived. They showed that closing the eyelids, placing a cellophane film on the cornea and blowing nitrogen over the cornea produced similar drops in anterior chamber oxygen tension. When pure oxygen was blown over the cornea, the oxygen tension in the anterior chamber rose.

It should be noted that the lens used in our project is thicker and less permeable to O<sub>2</sub> than the usual clinical contact lens, and the cats do not blink during the experiments. Also, there was no exchange of fluid film under the contact lens. However, some contact lenses used for patients decrease the precorneal O<sub>2</sub> level to zero,<sup>1</sup> and it would seem, therefore, that in

those cases, the anterior chamber oxygen tension would be lowered, as occurred in our experiments. The geometry of the anterior chamber is different in cats and humans and that has to be kept in mind when this data is interpreted.<sup>10</sup>

Pupil size was not monitored during these experiments. Research in our laboratory<sup>11,12</sup> has demonstrated that mydriasis caused by atropine does not affect anterior chamber oxygen tension.

The oxygen exchange between the cornea and the aqueous humor has two main effects with respect to wearing corneal contact lenses of low oxygen permeability: (1) The PO<sub>2</sub> in the aqueous humor may decrease. (2) The additional contribution of O<sub>2</sub> from the aqueous humor to the cornea during contact lens wear will assist the cornea in tolerating the impairment in atmospheric oxygen supply resulting from low O<sub>2</sub> permeability of the contact lens.

**Key words:** contact lens, oxygen, cornea, iris, aqueous humor

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