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ABSTRACT

Background / aims

To investigate the effect of hydroxypropylmethylcellulose (HPMC) on the physical interaction (contact angle) between silicone oil and a silicone intraocular lens (IOL).

Methods

In vitro experiments were performed, to determine the effect of HPMC (0.5%, 1% or 2%), with or without an additional simple mechanical manoeuvre, on the contact angle of silicone oil at the surface of both silicone and acrylic (control) IOLs. A balanced salt solution chamber was used. The study group comprised of 21 silicone and 9 acrylic IOLs.

Results

Median contact angle of silicone oil on silicone IOL was 99°. The addition of HPMC 2% alone did not significantly alter contact angle. HPMC 2% combined with an additional single mechanical manoeuvre increased contact angle to 180° (greater non-wetting), with complete separation of silicone oil from silicone IOL within 1 minute. The manoeuvre alone, or in conjunction with a lower concentration of HPMC (0.5 or 1%), was ineffective in increasing the contact angle.

Conclusion

We present a novel, non-toxic technique of using hydroxypropylmethylcellulose 2% combined with a simple mechanical manoeuvre, for the removal of adherent silicone oil droplets from silicone intraocular lenses.

INTRODUCTION

Persistent adherence of silicone oil onto the surface of silicone intraocular lenses (IOL) is a well-recognised and visually significant complication, following removal of silicone oil in vitreo-retinal patients [1-2]. Silicone IOLs are commonly implanted following cataract extraction[3], whilst silicone oil remains an important intraocular tamponade for the treatment of complicated retinal detachments[4-5].

Various techniques have been described to remove adherent silicone oil droplets from the posterior surface of silicone IOLs. Simple aspiration and irrigation techniques of the silicone oil droplets have been advocated by Eaton et al[6], Horgan and Cooling[7], and later Kageyama et al[8], although these are often ineffective[9-10]. Sodium hyaluronate 1.0% (Healon®, Provisc®) has also been tried but does not effectively disrupt the interaction between silicone oil and silicone IOL[1],. Partially fluorinated alkane solvents have been shown to be more effective[11-13], although they have the disadvantage of potential toxicity and require complete removal from the vitreous cavity. As a last resort, IOL explantation and exchange may be required to clear the visual axis[9].

In the presence of a posterior capsulotomy or capsular defect, condensation of the posterior surface of an IOL commonly occurs following fluid-air exchange during pars plana vitrectomy[14], resulting in a compromised view of the fundus and may complicate surgery. We regularly use hydroxypropylmethylcellulose (HPMC) 2% intra-operatively to coat the posterior IOL surface to remove condensation. Anecdotally, in such cases, when silicone oil endotamponade was subsequently used, we noticed early post-operative silicone oil emulsification. This observation raised the possibility of using HPMC 2% to remove adherent silicone oil droplets from silicone IOLs. Hydroxypropylmethylcellulose 2% (e.g. Coatel™, Bausch & Lomb, New York, USA) is used as an ophthalmic viscosurgical device (OVD) in cataract surgery[15], and has been shown to be a safe intraocular agent[16] when left *in-situ* postoperatively.

In this study, we conducted *in vitro* experiments to investigate the effect of HPMC on the contact angle of silicone oil on the surface of silicone IOLs. Our hypothesis was that HPMC may increase the contact angle of silicone oil on a silicone surface. This may provide a rational physico-chemical basis for the use of HPMC for the removal of adherent silicone oil from silicone IOL surfaces in a clinical setting. We are not aware of any published reports investigating the effect of HPMC on silicone oil and silicone IOL interaction.

MATERIALS AND METHODS

Two IOL materials were evaluated *in vitro*: three-piece foldable silicone IOL (SoFlex™ SE, Bausch & Lomb) and single-piece foldable hydrophilic acrylic IOL (Akreos® Adapt, Bausch & Lomb), both with power of +20.0 dioptres. OVDs used in the experiments were HPMC, and sodium hyaluronate (SH).

Each IOL was immersed in a fixed-volume balanced salt solution (BSS®; Alcon Labs Inc, Texas, USA) chamber to simulate an aqueous environment, and mounted horizontally. A fixed 5 µl volume of 1300 centistoke silicone oil (Arciolane® 1300, Arcadophta, Toulouse, France) was placed onto the IOL surface within the BSS chamber, and allowed to settle for 5 minutes. Senn et al[17] have shown that the length of exposure (1 minute versus 420 days) has no bearing on the interaction between silicone oil and silicone IOLs. Silicone oil was pre-stained with Oil Red O for better visualisation. The diameter of the silicone oil droplet was measured using a 20× light microscope with graticule (Peak Optics, Japan). In this study, each individual experiment type was repeated 3 times – total study group comprised 21 silicone and 9 acrylic IOLs. Using a sessile drop technique as described by the authors KP and IPP[18], contact angle can be calculated knowing both the diameter and volume of the droplet. This is a standard and relatively simple technique for calculating contact angle, and has been validated against an alternative technique of direct contact angle measurement[19]. Once the experiment has been set-up, each measurement takes approximately 2 minutes to perform. Further silicone oil diameters were measured, following injection of different concentrations of HPMC (2%, 1% and 0.5%; Moorfields Eye Hospital Pharmacy, London, UK), or sodium hyaluronate 1% (Provisc®; Alcon Labs Inc, Texas, USA) over the silicone oil droplet, which was allowed to stand for a further 5 minutes. A minimum of 2 mls of OVD was injected each time, ensuring both the entire silicone oil droplet, and adjacent IOL surface were adequately coated with OVD. These experiments were repeated with an additional mechanical manoeuvre of a single side-to-side sweeping of a 30-gauge Rycroft cannula between the IOL surface and silicone oil droplet, ensuring that the length of the cannula was flat against the IOL surface through the manoeuvre to facilitate maximal disruption of adherent silicone oil droplet from the IOL.

The sessile drop technique enables determination of the affinity of a liquid for a solid substrate, via contact angle measurements. Contact angle is the angle at which a liquid interface meets a solid (Figure 1). Increasing contact angle indicates greater non-wetting of a liquid on a solid (e.g. water on a hydrophobic surface). In the case of silicone oil on a silicone IOL, strong interacting forces between the polysiloxane chains result in greater wetting and a relatively low contact angle, which would partly explain the presence of persistent adherent silicone oil droplets.

RESULTS

Table 1 summarises the results. Median contact angle of silicone oil on silicone IOL in a BSS environment was approximately 99°. The addition of HPMC 2% alone did not significantly alter contact angle. HPMC 2% combined with an additional single side-to-side mechanical manoeuvre with a Rycroft cannula between silicone oil droplet and silicone IOL, increased contact angle (Figure 2) to a median of 180°, with subsequent complete separation of silicone oil from silicone IOL within 1 minute. The manoeuvre alone, or in conjunction with a lower concentration of HPMC (0.5 or 1%), was ineffective in increasing contact angle.

Table 1. Summary of contact angle measurements.

Lens type	**OVD type**	**+/- manoeuvre**	**Contact angle (degrees)** §			**Silicone oil separation?**
Silicone	-	-	85	**99**	114	-
	HPMC 2%	-	99	**99**	99	-
	-	+	76	**85**	89	-
	HPMC 2%	**+**	180	**<u>180</u>**	180	**+ (< 1 minute)**
	HPMC 1%	+	57	**68**	85	-
	HPMC 0.5%	+	57	**76**	99	-
	SH 1%	+	85	**93**	105	-
Acrylic	-	-	180	**180**	180	-
	-	+	180	**180**	180	-
	HPMC 0.5%	-	*	*	*	+ (immediate)

*contact angle immeasurable, as immediate separation of silicone oil droplet from IOL

§Three of each experiment type was performed. Middle column represents median contact angle.

Acrylic IOL was highly non-wetting in relation to silicone oil, with a median contact angle of 180°. The addition of HMPC 0.5% caused immediate separation of silicone oil droplet.

DISCUSSION

Our results show that silicone oil droplets can be effectively separated from silicone IOLs, using the combination of HPMC 2% and a single mechanical side-to-side sweeping manoeuvre of a Rycroft cannula between the silicone oil droplet and IOL. HPMC (0.5, 1 or 2%) alone is ineffective in separating silicone oil from silicone IOL. The addition of a mechanical sweeping manoeuvre appears to act as an adjunct to the HPMC 2%, disrupting the interaction between silicone oil and silicone IOL to cause complete separation of the silicone oil droplet.

We believe the mechanical sweeping manoeuvre temporarily disrupts the non-covalent interactions between silicone oil and silicone IOL, creating a transient gap between both surfaces that is immediately occupied by the surrounding HPMC 2%. We theorise that HPMC, with known emulsifiying properties, can disrupt the strong interaction between polysiloxane chains, thereby increasing the contact angle to 180°, resulting in non-wetting and complete dissociation of silicone oil droplets from the silicone IOL surface (Figure 3). However, it appears that a mechanical manoeuvre is also required to initiate disruption of the polysiloxane interactions. Without agitating the adherent silicone oil, we conclude that the HPMC in solution cannot adequately influence the surface tension of the silicone oil droplet at the silicone IOL surface. As we have shown in our experiments, the mechanical manoeuvre alone is not sufficient to disrupt the non-covalent interactions between the silicone oil and silicone IOL.

Contact angle between silicone oil and acrylic IOL in our experiments indicated non-wetting with minimal silicone oil adherence. This is consistent with previous studies[20-21]. It is therefore not surprising that a lower concentration of HPMC 0.5% was sufficient to cause separation of silicone oil from acrylic IOL.

There was some evidence of measurement variability within each set of 3 repeated experiments. This could in part be attributed to minor surface variabilities between IOLs. In addition, the manner in which the silicone oil droplets were applied could also have affected measurements. The use of an automated instead of a manual silicone oil applicator may reduce variability. The variability in our measurements is unlikely to be significant, as the technique was able to quickly determine if an IOL was hydrophobic or hydrophilic.

We were unable to demonstrate a significant dose dependent effect between HPMC 0.5% and 1% on contact angle between silicone oil and silicone IOL. The small number of experiments performed may not reveal small differences in contact angles. A true lack of dose dependency is unlikely, as HPMC 0.5% was effective on acrylic IOL as discussed above. An alternative method of assessing the effect of HPMC on silicone oil adherence to silicone IOL, is to measure the percentage of silicone oil coverage (surface area) of the lens optic[22], before and after HPMC. This may provide a more direct measure of the change of silicone oil adherence.

We have since used this technique in 3 patients who have had visual symptoms from adherent silicone droplets in the visual axis of silicone IOL surfaces. We have been able to successfully remove adherent silicone oil droplets in all 3 cases (Figure 4), with improvement in visual acuity, without post-operative adverse effects, or recurrence of silicone oil droplet adherence. A larger study will be required to confirm this.

HPMC 2% has been shown to be safe when left in-situ post-operatively[16]. This technique is favourable over IOL explantation or perfluorocarbon liquids[11-13], which require complete and meticulous removal from the posterior segment due to the risk of post-operative retinal toxicity[22]. HPMC 2% is widely available commercially as it is currently used as an ophthalmic viscosurgical device during anterior segment surgery.

In summary, we present a novel technique of using hydroxypropylmethycellulose 2% combined with a simple mechanical manoeuvre, for the removal of adherent silicone oil droplets from silicone intraocular lenses.

Competing interests and funding: nil

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LEGENDS

Table 1.

Summary of contact angle measurements.

Figure 1.

Contact angle (Θ) of a liquid (L) on a solid (S). γ_{LV} = interfacial energy of liquid-vapour interface, γ_{SL} = interfacial energy of solid-liquid interface, γ_{SV} = interfacial energy of solid-vapour interface.

Figure 2.

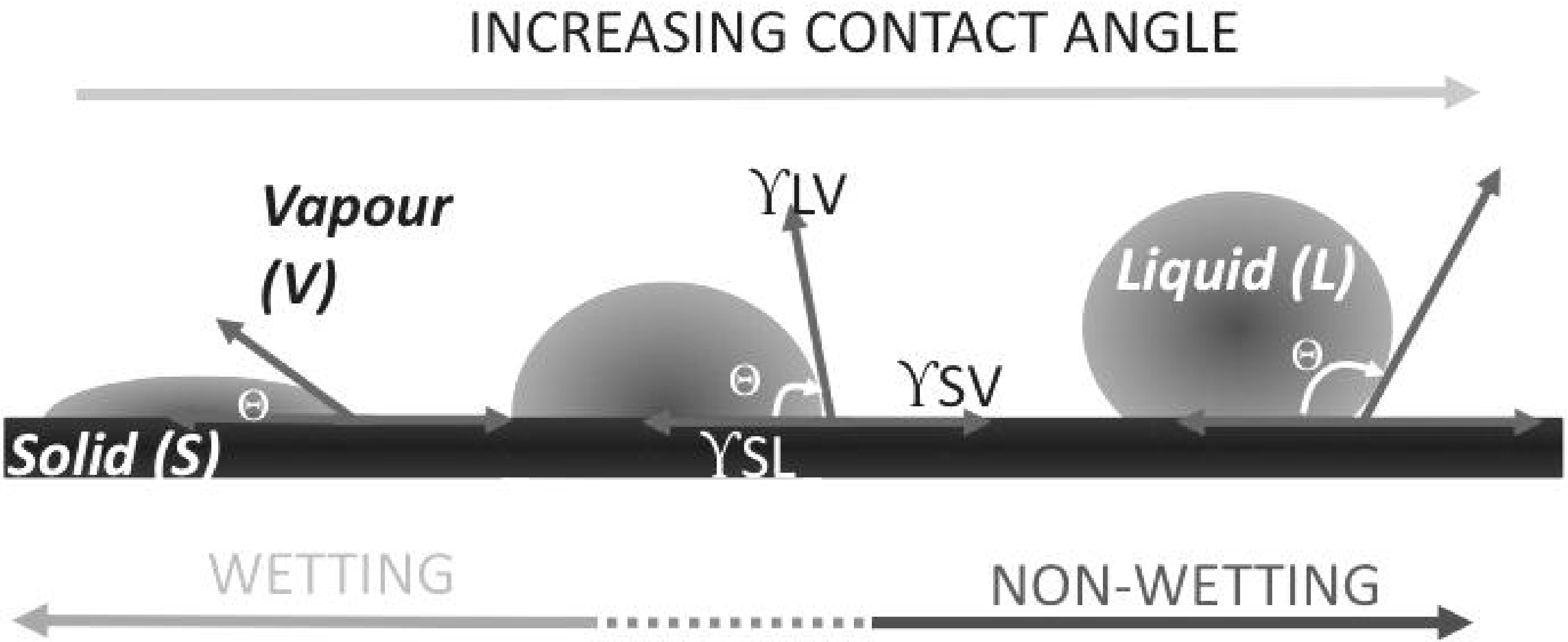
Contact angle of silicone oil droplet on silicone IOL(Θ) is increased by HPMC 2% combined with an additional single side-to-side mechanical manoeuvre with a Rycroft cannula between silicone oil droplet and silicone IOL. γ_{LV} = interfacial energy of liquid-vapour interface, γ_{SL} = interfacial energy of solid-liquid interface, γ_{SV} = interfacial energy of solid-vapour interface.

Figure 3.

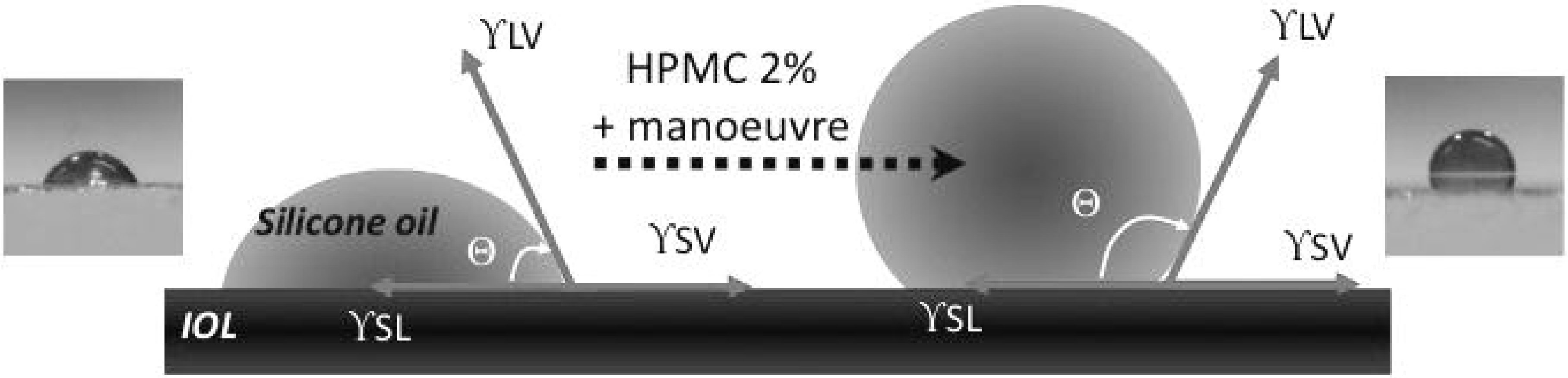
In vitro experiment - silicone oil droplet on silicone IOL in BSS chamber. A, Silicone oil droplet, stained with Oil Red O, adherent to silicone IOL surface (arrow). B, Following addition of HPMC 2% with mechanical sweeping manoeuvre, contact angle of silicone oil increased to 180 degrees, with subsequent complete separation of silicone oil droplet from IOL (arrow head).

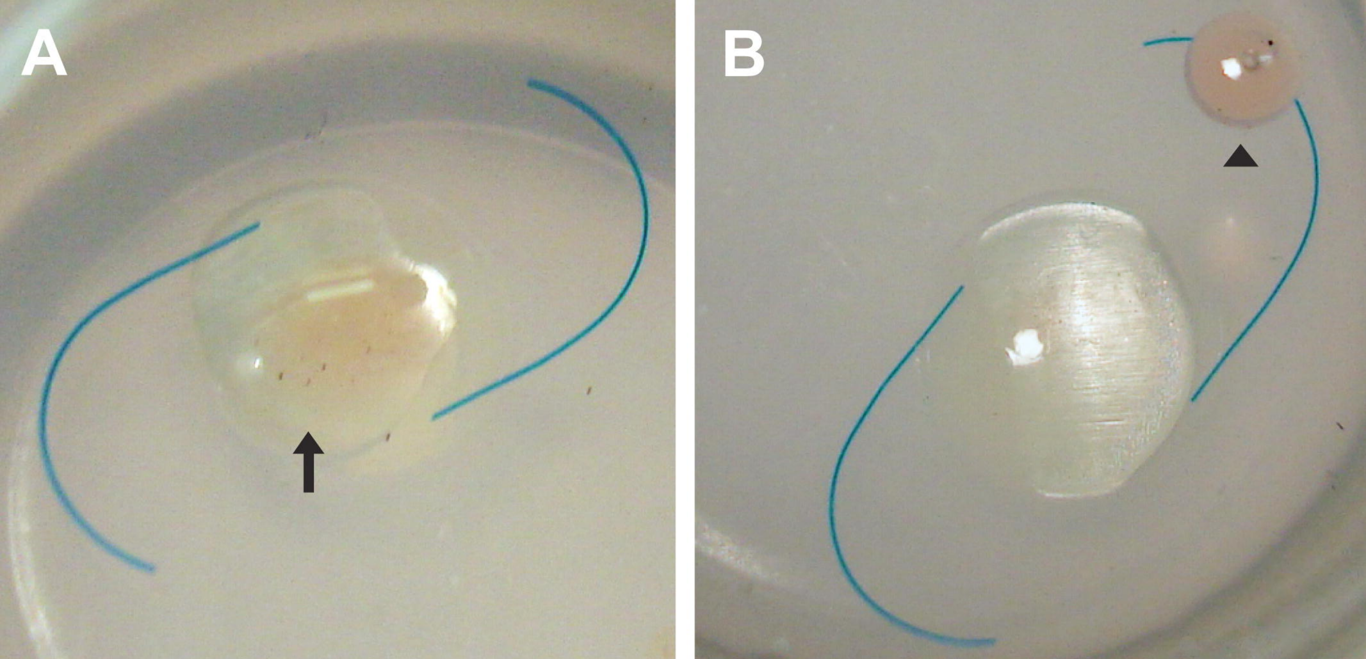
Figure 4.

In vivo silicone oil (arrow) removal. A, Adherent silicone oil droplet on posterior surface of optic of posterior chamber silicone IOL. B, C, Mechanical sweeping manoeuvre being performed following addition of HPMC 2% - silicone oil droplets are seen separating from IOL. D, Silicone oil has separated from IOL, leaving a clear central optic.


INCREASING CONTACT ANGLE
Vapour
(V)
ϒLV
Liquid (L)
Θ
Θ
Θ
ϒSV
Solid (S)
ϒSL
WETTING
NON-WETTING

2% HPMC + mechanical manoeuvre increases contact angle of silicone oil at a silicone surface

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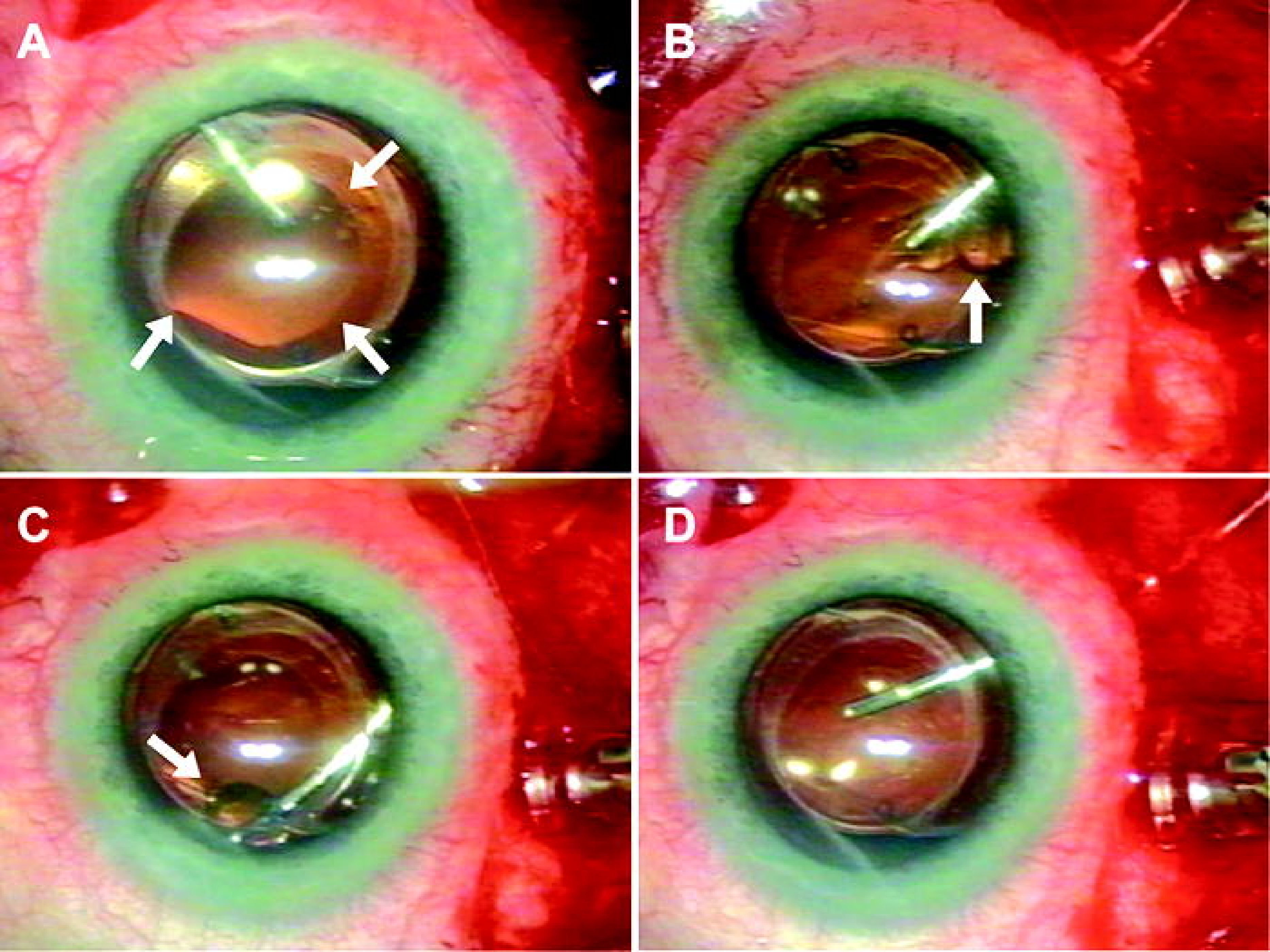
A
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