SCIENTIFIC REPORT

Retention and removal of a new viscous dispersive ophthalmic viscosurgical device during cataract surgery in animal eyes

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Aims: To assess the retention and removal properties of a new viscous dispersive ophthalmic viscosurgical device (OVD), DisCoVisc, in comparison with those of cohesive (Provisc), dispersive (Viscoat), and viscoadaptive (Healon5) OVDs.

Methods: In 20 porcine eyes, cataract surgery was simulated using one of the four OVDs which were stained with fluorescein for better visualisation. Three parameters were measured. Firstly, the presence/absence of OVDs in the chamber at the completion of phacoemulsification was recorded. Secondly, the time until the OVDs were completely removed from the anterior chamber using the phaco needle was measured. Thirdly, after intraocular lens (IOL) implantation, the time needed to completely remove the OVDs from the chamber with irrigation/aspiration tip was recorded.

Results: At the completion of phacoemulsification, the OVDs retained in 0% (0/5) for Provisc, 80% (4/5) for Healon5, 100% (5/5) for DisCoVisc, and 100% (5/5) for Viscoat. The retention of OVDs during phacoemulsification was greatest with Viscoat followed by, in descending order, DisCoVisc, Healon5, and Provisc. The removal of OVDs after IOL implantation took longest with Viscoat followed by Healon5, DisCoVisc, and Provisc.

Conclusion: The viscous dispersive DisCoVisc showed excellent retention during phacoemulsification, while its removal after IOL implantation was very easy. When compared with the viscoadaptive Healon5, DisCoVisc was retained better in the chamber and was easier to remove. These features of DisCoVisc should be highly advantageous when considering covering the entire cataract surgery procedure with a single OVD.

Ophthalmic viscosurgical devices (OVDs) have become the essential tools in ocular surgery, especially in anterior segment surgery. There are several OVDs available on the market. The property of a viscoelastic formulation is closely tied to its physicochemical and rheological properties.^{1,2} Higher viscosity cohesive OVDs and lower viscosity dispersive OVDs have their own unique advantages and disadvantages. High viscosity cohesive OVDs help maintain and preserve space as well as displace and stabilise tissues. These materials, however, tend to easily flow out of the eye during phacoemulsification. Low viscosity dispersive OVDs tend to remain in the eye adjacent to the corneal endothelium, providing potential protection during phacoemulsification. The disadvantages of this type of OVD are that it poorly maintains space and is sometimes difficult to remove.

A viscoadaptive viscoelastic, Healon5, belongs to another class of OVDs.^{3–5} Its distinguishing characteristic is the rheological behaviour changes under varying conditions of turbulence. It acts as a very viscous, cohesive viscoelastic agent at low flow rate and as a pseudodispersive viscoelastic agent at higher flow rate. A previous clinical study demonstrated that the viscoadaptive OVD (Healon5) was superior to the cohesive OVD (Healon) in retention during phacoemulsification, anterior chamber maintenance during anterior capsulotomy, and facilitation of intraocular lens (IOL) implantation.⁶ On the other hand, injection and removal of the viscoadaptive OVD were judged to be more difficult than the cohesive OVD.⁶

Recently, a new class of OVD, DisCoVisc, has been developed and completed the FDA phase III clinical trial. DisCoVisc is a viscoelastic solution of sodium chondroitin sulfate and sodium hyaluronate, having a viscosity of 75 000 (SD 35 000) millipascal seconds (mPas) at shear rate of 1 s⁻¹ and 25°C. Each millilitre of DisCoVisc contains not more than 40 mg sodium chondroitin sulfate and 17 mg sodium hyaluronate. It has been claimed that DisCoVisc has an intermediate cohesive/dispersive index, facilitating both space maintenance and tissue protection. The intraoperative characteristics of DisCoVisc, however, have not been reported. We conducted the current experimental study to evaluate retention and removal properties of DisCoVisc, which were compared with those of cohesive, dispersive, and viscoadaptive OVDs.

SUBJECT AND METHODS

In 20 eyes from newly slaughtered pigs, cataract surgery was simulated using DisCoVisc (Alcon), Provisc (Alcon), Viscoat (Alcon), or Healon5 (AMO). For better visualisation, OVDs were stained with fluorescein. A corneal tunnel incision was created with a 3.0 mm angled slit knife, and one of the OVDs was injected until the anterior chamber was filled with the OVD. A continuous curvilinear capsulorhexis was created, and phacoemulsification was performed using a phacoemulsifier (Infiniti, Alcon) with a fixed flow rate of 35 ml/min and linear vacuum level of 300 mm Hg at maximum. A 20 gauge straight phaco needle with a 30 degree angulated tip without a bypass hole was used at 30% power. Bottle height was 85 cm above the eye. If the OVDs remained in the eye at the completion of phacoemulsification, aspiration with the phaco needle was continued until the OVDs were completely removed from the chamber. Then, the capsular bag was filled with the OVD, and an intraocular lens (IOL) (SA60AT, Alcon) was implanted within the capsular bag using the Monarch II inserter. After IOL implantation, the OVDs were thoroughly washed out using the irrigation/aspiration (I/A)

Abbreviations: I/A, irrigation/aspiration; IOL, intraocular lens; OVD, ophthalmic viscosurgical device

Figure 1 The time until the OVDs were completely removed from the chamber using phaco needle (mean (SD)). There was a significance difference among the four groups ($p < 0.001$, ANOVA). *The Bonferroni multiple comparison revealed significant differences between Provisc and DisCoVisc ($p = 0.002$), Provisc and Viscoat ($p < 0.001$), Healon5 and DisCoVisc ($p = 0.034$), Healon5 and Viscoat ($p < 0.001$), and DisCoVisc and Viscoat ($p = 0.02$).

tip, with fixed flow rate of 40 ml/min and linear vacuum level of 600 mm Hg at maximum. For Healon5, the behind the lens technique was used for washout.^{7,8}

Three parameters were measured. Firstly, the presence/absence of OVDs in the chamber at the completion of phacoemulsification was recorded. Secondly, the time from the initiation of phacoemulsification to the complete removal of OVDs from the anterior chamber was measured, using the phaco needle until the OVDs were completely removed from the chamber. Thirdly, after the implantation of an IOL, the time needed to completely remove the OVDs from the chamber with an I/A tip was recorded. The time was measured by the phacoemulsifier which records the duration for which the aspiration pump is activated. The complete removal of the OVD was confirmed by the direct observation under the operating microscope and the side view of the eye magnified and recorded by a video camera.

RESULTS

Each OVD was tested in five porcine eyes. At the completion of nucleus removal, the OVDs labelled by fluorescein retained in 0% (0/5) for Provisc, 80% (4/5) for Healon5, 100% (5/5) for DisCoVisc, and 100% (5/5) for Viscoat.

The time until the OVDs were completely removed from the chamber using the phaco needle is shown in figure 1. There was a significant difference among the four groups

Figure 2 The time needed to completely remove the OVDs from the chamber with irrigation/aspiration tip, after IOL implantation (mean (SD)). There was a significance difference among the four groups ($p < 0.001$, ANOVA). *The Bonferroni multiple comparison revealed significant differences between Provisc and Viscoat ($p < 0.001$), Healon5 and Viscoat ($p < 0.001$), and DisCoVisc and Viscoat ($p < 0.001$).

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The time needed to completely remove the OVDs from the chamber with the I/A tip, after IOL implantation, is shown in figure 2. There was a significant difference among the four groups ($p < 0.001$, ANOVA). The Bonferroni multiple comparison revealed significant differences between Provisc and Viscoat ($p < 0.001$), Healon5 and Viscoat ($p < 0.001$), and DisCoVisc and Viscoat ($p < 0.001$).

DISCUSSION

In this study, we simulated cataract surgery in porcine eyes to test the retention and removal properties of OVDs. As the first parameter, we assessed the retention of OVDs at the completion of phacoemulsification. It was found that the cohesive Provisc was not retained in the eye at all. On average, Provisc was completely gone in 8.2 (SD 4.9) seconds. On the other hand, the viscoadaptive Healon5 was retained in the chamber in 80% of eyes. The viscous dispersive DisCoVisc and the dispersive Viscoat were retained in the chamber in 100% of eyes.

Next, we tried to assess how much volume of OVDs was left at the time of completion of phacoemulsification. Because direct measurement of remnant volume was impossible, we instead measured the time until the complete removal of the OVDs from the chamber using a phaco needle. The removal time does not exactly parallel the remnant volume of OVDs, and is related to the ease/difficulty of aspiration of the OVDs. We thought that, however, the removal time reflects how long the OVDs remain in the eye and protect the ocular tissues during phacoemulsification, which usually takes much longer in human eyes than in animal eyes. As shown in figure 1, there was a significant difference in the average removal time of the four OVDs. It has been known that dispersive OVDs are retained in the eye better than the cohesive OVDs,⁹⁻¹² and that cohesive OVDs are removed faster than viscoadaptive OVDs.⁶ However, there has been a clinical report that retention of Healon5 in the anterior chamber during phacoemulsification was better than that of Viscoat,⁵ which is opposite to the current results. At present, we do not have a clear explanation for this discrepancy. A novel observation in this study is that DisCoVisc is retained very well during phacoemulsification, the clinical significance of which is discussed below.

Thirdly, after IOL implantation, we measured the time needed to completely remove the OVDs from the chamber with an I/A tip. This parameter seems to be similar to the second one mentioned above, but there are several different implications. It has been known that the presence of IOL and its optic material influence the removal time of OVDs.^{12,13} Special removal techniques are needed to remove Healon5 in the presence of an IOL.^{7,8,13} The machine settings, including flow rate and vacuum limit, as well as port diameter are different between phacoemulsification needle and I/A tip. Moreover, this third parameter is the measure of removal property, while the second parameter is to assess the retention ability of OVDs.

As shown in the results, the removal time of OVDs with an I/A tip was longer with dispersive Viscoat and shorter with cohesive Provisc, which is consistent with the results of previous studies.^{9,12} The removal of viscoadaptive Healon5 was faster than Viscoat, but slower than Provisc, which again agrees with previous reports.²⁻⁶ The removal time of DisCoVisc was found to be shorter than Healon5 and longer than Provisc.

This study represents the first report of retention and removal characteristics of viscous dispersive OVD DisCoVisc. As has been anticipated, the retention and removal properties of DisCoVisc fell between cohesive Provisc and dispersive Viscoat. Interestingly, DisCoVisc was retained in the anterior chamber during phacoemulsification better than Healon5 (fig 1), while removal of DisCoVisc with I/A tip was easier than Healon5 (fig 2). The better retention of DisCoVisc during phacoemulsification seems to be the result of the more dispersive property of DisCoVisc, against the pseudo-dispersive nature of Healon5. On the other hand, Healon5 is difficult to wash out at the end of surgery because of the presence of an IOL; Healon5 is often trapped behind the IOL,² especially so with the acrylic foldable IOL.¹³ The viscoadaptive OVDs are so rigid to permit scrolling around obstacles in the eye (IOLs), resulting in interrupted contact with the aspiration port.² The OVD fragment behind the IOL is exposed to too little turbulent flow to move towards the aspiration port unless the I/A tip is placed behind the IOL or a special technique is used. On the other hand, DisCoVisc is not so rigid and has sufficient cohesion to stay together in the presence of aspiration and is supple enough to bend around obstacles. In our experiments, the behind the lens technique was not necessary for the washout of DisCoVisc.

One of the weaknesses of our study is that we used only one flow and vacuum setting. For phacoemulsification, a fixed flow rate of 35 ml/min and linear vacuum level of 300 mm Hg at maximum were used. For I/A, flow rate was fixed to 40 ml/min and vacuum level was set to liner 600 mm Hg. In a preliminary study, we tested several different flow and vacuum settings, and found that obtained data did not differ significantly depending on the settings (data not shown). We therefore used a single setting with which we were most familiar in practice.

Another limitation of our study is that this was an experimental study in animal eyes. Living human eyes and enucleated animal eyes are different in anatomy, structure, and physiological conditions. Therefore, the current results may not directly apply to clinical situations. In addition, our study lacks the data on corneal endothelial cell loss. This issue will be the subject of future studies in human eyes.

In conclusion, our cataract surgery simulation study in porcine eyes demonstrated that viscous dispersive DisCoVisc showed excellent retention during phacoemulsification, while its removal after IOL implantation was very easy. The retention and removal properties of DisCoVisc were in between cohesive and dispersive OVDs. When compared with the viscoadaptive Healon5, DisCoVisc was better

retained during phacoemulsification and was easier to remove after IOL implantation. These features of DisCoVisc should be highly advantageous when we consider covering the entire cataract surgery procedure with a single OVD.

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REFERENCES

- 1 **Arshinoff SA.** Dispersive-cohesive viscoelastic soft shell technique. *J Cataract Refract Surg* 1999;**25**:167-73.
- 2 **Arshinoff SA, Wong E.** Understanding, retaining, and removing dispersive and pseudodispersive ophthalmic viscosurgical devices. *J Cataract Refract Surg* 2003;**29**:2318-23.
- 3 **Schwenn O, Dick HB, Krummenauer F, et al.** Healon5 versus Viscoat during cataract surgery: intraocular pressure, laser flare and corneal changes. *Graefes Arch Clin Exp Ophthalmol* 2000;**238**:861-7.
- 4 **Dick HB, Krummenauer F, Augustin AJ, et al.** Healon5 viscoadaptive formulation: comparison to Healon and Healon GV. *J Cataract Refract Surg* 2001;**27**:320-6.
- 5 **Tetz MR, Holzer MP, Lundberg K, et al.** Clinical results of phacoemulsification with the use of Healon5 or Viscoat. *J Cataract Refract Surg* 2001;**27**:416-20.
- 6 **Oshika T, Eguchi S, Oki K, et al.** Clinical comparison of Healon5 and Healon in phacoemulsification and intraocular lens implantation; randomized multicenter study. *J Cataract Refract Surg* 2004;**30**:357-62.
- 7 **Tetz MR, Holzer MP.** Two-compartment technique to remove ophthalmic viscosurgical devices. *J Cataract Refract Surg* 2000;**26**:641-3.
- 8 **Zetterstrom C, Wejde G, Taube M.** Healon5: comparison of 2 removal techniques. *J Cataract Refract Surg* 2002;**28**:1561-4.
- 9 **Assia EI, Apple DJ, Lim ES, et al.** Removal of viscoelastic materials after experimental cataract surgery in vitro. *J Cataract Refract Surg* 1992;**18**:3-6.
- 10 **Poyer JF, Chan KY, Arshinoff SA.** New method to measure the retention of viscoelastic agents on a rabbit corneal endothelial cell line after irrigation and aspiration. *J Cataract Refract Surg* 1998;**24**:84-90.
- 11 **McDermott ML, Hazlett LD, Barrett RP, et al.** Viscoelastic adherence to corneal endothelium following phacoemulsification. *J Cataract Refract Surg* 1998;**24**:678-83.
- 12 **Auffarth GU, Holzer MP, Vissessook N, et al.** Removal times for a dispersive and a cohesive ophthalmic viscosurgical device correlated with intraocular lens material. *J Cataract Refract Surg* 2004;**30**:2410-4.
- 13 **Auffarth GU, Holzer MP, Vissessook N, et al.** Removal times and techniques of a viscoadaptive ophthalmic viscosurgical device. *J Cataract Refract Surg* 2004;**30**:879-83.