

Understanding the Clinical Behavior of Ophthalmic Viscoelastic Devices

D. Michael Colvard, MD, FACS

Ophthalmic viscoelastic devices (OVDs) are fundamental tools in modern cataract surgery. These materials coat and protect delicate intraocular tissues, maintain the relationships of ocular structures, create space, and improve visualization. The successful outcome of a difficult or complex cataract procedure often hinges on a surgeon's knowledge of OVDs, and his or her ability to select the OVD or combination of OVDs that best meets the specific challenges of the case.

Understanding the clinical behavior of OVDs is actually quite simple. There are two key points. The first is that the physical properties and characteristics of OVDs are defined primarily by the molecular chain length of the material. The second is that these properties and characteristics change in a predictable fashion under different conditions of fluid movement within the eye. With a little basic knowledge, one can quickly learn to look at the package insert of any OVD and predict with a great deal of confidence how the material is likely to perform clinically.

In clinical terms, OVDs generally may be classified either as "cohesive" or "dispersive" in character. Molecular chain length is the primary determinant of "cohesive" or "dispersive" clinical behavior.

COHESIVE OPHTHALMIC VISCOELASTIC DEVICES

Cohesive OVDs such as Healon and Healon GV (AMO, Santa Ana, CA), Provisc (Alcon, Fort Worth, TX), Amvisc (Bausch & Lomb, Rochester, NY), and Staarvisc II (STAAR Surgical, Monrovia, CA) are high molecular weight, long-chained sodium hyaluronate OVDs (range of molecular weight 1,000,000 to 7,000,000 Daltons). These high molecular weight OVDs are referred to as "cohesive" because their long molecular chains tend to interlock and intertwine. This causes the molecules of these OVDs to become entangled and behave intraocularly as a cohesive unit.

DISPERSIVE OPHTHALMIC VISCOELASTIC DEVICES

Dispersive OVDs such as Healon D (AMO) and Viscoat (Alcon) are low molecular weight, short-chained sodium hyaluronate OVDs. The molecular weight of sodium hyaluronate for both Healon D and Viscoat is approximately 500,000 Daltons. Viscoat has an additional material, chondroitin sulfate, which has a molecular weight of approximately 25,000 Daltons. These low molecular weight OVDs are referred to as



Figure 11-1A. Cohesive OVDs behave like jelly or jam under conditions of zero shear (when there is no fluid movement in the eye). The long-chained molecules of cohesive OVDs tend to intertwine and “lock in position.” This creates a scaffolding effect intraocularly that helps these OVDs to maintain space very effectively.

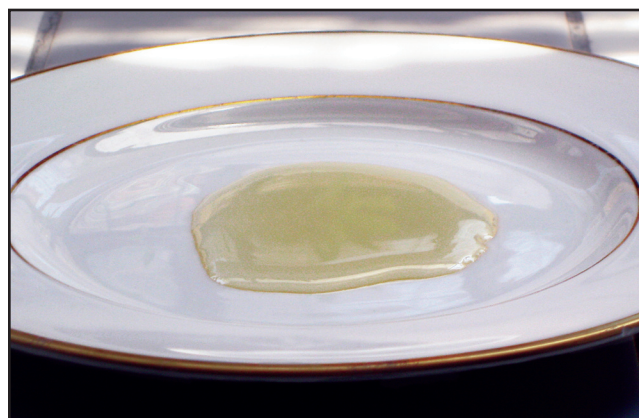


Figure 11-1B. Dispersive OVDs behave like honey at zero shear. The short-chained molecules of dispersive OVDs tend to slide over one another and puddle. In general, dispersive OVDs are good at coating intraocular structures but are not as effective as cohesive materials at maintaining surgical space.

“dispersive” because their short molecular chains do not interlink or become entangled easily. This causes the molecules of these OVDs to separate from one another and behave in a dispersive manner.

DEFINING ZERO SHEAR VS HIGH SHEAR CONDITIONS

Cohesive and dispersive OVDs behave predictably under different conditions of fluid movement within the eye. Zero shear is a term used to describe a condition when there is no fluid movement within the eye. Capsulorrhexis performed in an anterior chamber filled with an OVD is an example of a zero shear condition. High shear describes a condition when there is a high rate of fluid movement within the eye. High shear conditions exist during phacoemulsification and during aspiration/irrigation.

OPHTHALMIC VISCOELASTIC DEVICE BEHAVIORS AT ZERO SHEAR

Cohesive Ophthalmic Viscoelastic Devices

During conditions of zero shear, the long-chained molecules of cohesive OVDs tend to intertwine and “lock in position.” This creates a scaffolding effect

intraocularly that helps these OVDs to maintain space very effectively. This quality makes cohesive OVDs more retentive when there is no fluid movement in the eye, and ideal for surgical challenges that require difficult intraocular maneuvers such as intraocular lens (IOL) exchanges. Higher molecular weight cohesive OVDs such as Healon (AMO) and Healon GV are more retentive than lower molecular weight cohesive OVDs such as Provisc (Figure 11-1A).

Dispersive Ophthalmic Viscoelastic Devices

The short-chained molecules of dispersive OVDs tend to slide over one another and create a puddle under conditions of zero shear. The concentrations of dispersive low molecular weight OVDs are generally higher (range ~3% to 4%) than that of cohesive longer chained OVDs (range ~1% to 2.3%). The concentration is increased in an effort to increase the zero shear viscosity of these shorter chained materials. An increase in concentration increases to some degree the retentiveness of short-chained OVDs and prevents these materials from being excessively “runny.” In general, however, dispersive OVDs are not as effective as cohesive materials at maintaining surgical space under conditions of zero shear (Figure 11-1B).



Figure 11-2A. Long-chained molecules of cohesive OVDs behave like spaghetti during conditions of high shear. They tend to entangle and leave the eye as a bolus. This makes cohesive materials much easier to remove at the conclusion of a procedure.



Figure 11-2B. Short-chained molecules of dispersive OVDs under conditions of high shear behave like penne. The molecules do not tend to interlink and stay in the anterior chamber much more effectively than do cohesive OVDs. For this reason, dispersive OVDs of sodium hyaluronate provide superior endothelial protection in conditions of high shear, especially during phacoemulsification.

OPHTHALMIC VISCOELASTIC DEVICE BEHAVIORS AT HIGH SHEAR

Cohesive Ophthalmic Viscoelastic Devices

The long-chained molecules of cohesive OVDs, under conditions of high shear, tend to entangle and leave the eye as a bolus. This makes cohesive materials much easier to remove at the conclusion of a procedure, but less protective than dispersive OVDs during phacoemulsification (Figure 11-2A).

Dispersive Ophthalmic Viscoelastic Devices

Dispersive OVDs of sodium hyaluronate provide superior endothelial protection during phacoemulsification. The short-chained molecules tend to slide over themselves and coat intraocular structures in a honey-like fashion. In addition, because the short-chained molecules do not tend to interlink, dispersive OVDs tend to stay in the anterior chamber much more effectively during phacoemulsification than cohesive OVDs. This dispersive quality, however, ceases to be an asset when it is time to remove the viscoelastic material at the end of a case. Complete removal of sodium hyaluronate dispersive OVDs is difficult because the molecules do not tend to join together and do not aspirate as a unit (Figure 11-2B).

THE ADVANTAGES OF USING DISPERSIVE AND COHESIVE OPHTHALMIC VISCOELASTIC DEVICES TOGETHER

Many surgeons, in order to obtain the best qualities of both dispersive and cohesive OVDs, use the two types of OVDs in combination. A dispersive OVD, such as Healon D, may be used at the beginning of a case to provide maximum endothelial protection during phacoemulsification. A cohesive OVD, such as Healon, may then be used at the time of IOL implantation both to provide excellent chamber maintenance and easy removal of the OVD, thereby reducing the chances of elevated intraocular pressure (IOP) post-operatively.

THE SPECIAL QUALITIES OF HEALON 5

Healon 5 is an unusual OVD that cannot be described adequately as either a cohesive or a dispersive agent. Depending on conditions of flow, it has qualities of both. Healon 5 has both a high molecular weight (4,000,000 Daltons) and a relatively high molecular concentration (2.3%).

At zero shear, the long-chained molecules of Healon 5 lock together readily and act as a unit once

they are injected into the anterior chamber. The linkage of the long-chained molecules is enhanced by increased concentration of the material. As a result, Healon 5 is the most highly retentive of all OVDs at zero shear, allowing this material not only to maintain anterior chamber volume extraordinarily well but to move tissue and enlarge poorly dilating pupils as well.

Under conditions of low shear, when phacoemulsification parameters are set to low flow and low vacuum, the Healon 5 material can be fractured and compartmentalized. An arching dome of Healon 5 can be left above the pupillary plane which provides both endothelial protection and pupillary dilatation, while nucleus removal is accomplished in the posterior chamber.

During irrigation/aspiration, high shear conditions may be created by increasing both flow and vacuum, and Healon 5 becomes a super cohesive material that leaves the anterior chamber readily in a bolus. Special care must also be taken at the end of the case to remove all of the high molecular weight Healon 5 from beneath the IOL in order to prevent an elevation of IOP. Because of its unique clinical features, Healon 5 is very useful in the management of some of the most difficult challenges in cataract surgery, including small pupils unresponsive to mydriatics, iris prolapse, floppy iris syndrome, and the mature intumescent cataract. To understand the clinical applications of Healon 5 more completely, see Chapter 7 for a detailed description of its uses and indications.