Viscoelastics in Cataract Surgery

Dr. B. Ganesh MS

OVDs (viscoelastics) are substances that exhibit both viscous and elastic properties, and are most commonly used in cataract surgery, in other ophthalmic intraocular surgical procedures and as components of artificial tears and rewetting drops.

Since not all of the lower viscosity products are particularly elastic, and since some of the devices are elastoviscous rather than viscoelastic, the International Standards Organization (ISO) coined the term ophthalmic viscosurgical devices (OVD), harmonizing it with other device nomenclature in medicine and surgery. Healon (Sodium Hyaluronate 1 %,) was the first viscoelastic agent developed, and brought a revolution to the way traditional cataract surgery was performed.

OVDs provide essential protection of the corneal endothelium, and create and maintain working space during cataract and other intraocular surgery. With the advent of phacoemulsification, the need for OVDs possessing different physical properties for different surgical phases became apparent, leading to the development of the Soft Shell technique. Choosing the most effective OVD for a particular use is based on a thorough understanding of the properties and functions of the various products, and the physical nature of what the surgeon is trying to achieve.

Introduction

The use of viscoelastics for anterior segment surgery was introduced by Balazs in 1979 with Healon 3. Healon was the first viscoelastic substance introduced commercially (1980) for use in human intraocular surgery. Previously, air, balanced salt solution, and the patient’s plasma were used in cataract surgery to maintain space and to attempt to minimize contact of surgical instruments and the IOL with the corneal endothelium during intraocular lens implantation. Unfortunately, these substances lack sufficient viscosity and elasticity to prevent their escaping from large surgical wounds, often resulting in collapse of the anterior chamber at inopportune times.

Home-made hydroxypropylmethylcellulose 1% (HPMC), sourced from wood pulp, was then trialed as an OVD and for lubricating the implant during intraocular surgery. HPMC often contained impurities, possesses the lowest viscosity of all OVDs, and is poorly elastic, and minimally pseudoplastic. Poor pseudo plasticity (lack of decline in viscosity with increasing shear rate) causes it to require a large-bore cannula and increased infusion pressure for injection, thereby causing decreased feedback sensation for the surgeon.

In pursuit of an ideal OVD, various viscoelastic agents have been manufactured by modifying the rheologic components, their molecular weights, concentrations and mixtures, and thereby, their biomechanical properties. An ideal OVD should be biocompatible with ocular tissues, should be able to create and maintain space during intraocular surgical manipulation and should protect the corneal endothelium. It should also be able to be easily removed from the anterior chamber at the end of surgery, and should have little effect on post operative intraocular pressure (IOP) rise. It follows directly from the fact that the rheologic properties of an OVD are the result not only of its rheologic
polymer(s), but also of the molecular weight(s) of those polymers and their concentrations, included buffers, etc. that OVDs cannot be adequately referred to generically by their chief rheologic polymer and its concentration, but must be referred to by their trade names for full characterization of their makeup and surgical behavior, as for example, many companies may manufacture a 1 % sodium hyaluronate product, but they are all different in their rheologic properties.

Rheological properties such as elasticity, viscosity, pseudo plasticity and cohesion determine the performance of an OVD in surgery. Elasticity is the property of a substance to return to its original shape after being stretched, compressed or deformed.

Viscous fluids possess internal friction caused by molecular attractions resisting flow. Viscosity is the measure of this resistance to flow. Viscosity of a viscoelastic substance at rest is called zero shear viscosity, which is the only consistent measure of viscosity in a pseudoplastic fluid. Zero shear viscosity of an OVD is a function of its rheologic polymer, its molecular weight and concentration.

Pseudoplastic fluids demonstrate a decline in viscosity with increasing shear rate, and at very high shear rates, the viscosities of pseudoplastic fluids may dramatically decrease and become independent of the molecular weight, and is determined mainly by concentration. Viscoelasticity provides ocular protection against high frequency mechanical insults associated with phacoemulsification.

Pseudoplasticity is a property of non-Newtonian fluids, such as sodium hyaluronate. Some highly pseudoplastic fluids can be easily extruded through a thin cannula despite very high zero shear viscosities. Chondroitin sulfate, like air and water, is a newtonian substance, as it does not change its viscosity at different rates of shear. Pseudoplastic behavior of OVDs is often confused with surgical retention. Research has demonstrated that retention of an OVD within the anterior chamber during phaco is enhanced by three factors: greater dispersive properties, negative charge, and the presence of hyaluronic acid in the OVD, for which Madsen (1989) had earlier found specific endothelial binding sites. Of all OVDs marketed only Viscoat (Alcon, Fort Worth, Texas) and DisCoVisc (Alcon) score well on all three counts, as they possess hyaluronic acid, and the chondroitin sulfate component makes them more dispersive and enhances their negative surface charges.

Free radical formation has been related to ophthalmic phacoemulsification devices. OVDs reduce the oxidative damage caused by free radicals produced during phacoemulsification surgery. Both hyaluronic acid and chondroitin sulfate are known free radical scavengers. The antioxidant effect of the OVD depends on its molecular makeup and its retention in the anterior chamber during phacoemulsification; the more dispersive the agent the more retention is seen during and after phacoemulsification and irrigation-aspiration of cortex.

**Current Classification**

Initially, OVDs were classified into two kinds: higher viscosity cohesive and lower viscosity dispersive. Cohesion is the degree to which long-chain polymeric molecules entangle and is a function of the nature of the molecule and its chain length. Cohesive HA OVDs are high molecular weight (greater than 1 million Daltons) and possess high zero shear viscosity. Higher viscosity cohesive OVDs are best at creating and preserving space and inducing pressure in the eye. A major advantage of higher viscosity cohesive OVDs is their ability to induce and sustain pressure in an eye despite an incision, enabling pressure-equalized cataract surgery. This is important in performing consistent capsulorhexes, preventing the tear from running outwards, as it would when the pressure behind the anteriorly convex anterior capsule exceeds that in front of it, and to implant IOLs in stabilized open capsular bags.

They are also easily removed from the eye as a bolus during irrigation and aspiration especially in the presence of a large incision. Currently available viscous-cohesive OVDs include Healon (1 % sodium hyaluronate, 4 million Daltons), Provisc (1 % sodium hyaluronate, 2.4 million Daltons), Amvisc Plus (1.6 % sodium hyaluronate, 1.5 million Daltons, Bausch and Lomb, B&L, Rochester, N.Y.), Amvisc (1.2 % sodium hyaluronate, 2 million Daltons, B&L), and many others. Healon GV is a super viscous cohesive OVD (1.4 % sodium hyaluronate, 5 million Daltons) with a zero
shear viscosity of 2,000,000 milli Pascal seconds (mPaS), about 10 times the zero-shear viscosity of regular viscous cohesive OVDs, which results in it being able to perform all of the tasks above of a viscous-cohesive OVD better.

While any OVD, if retained in the anterior chamber after surgery, can result in increased postoperative IOP, very high IOP spikes can occur if a large amount of a highly viscous cohesive OVD is left in the eye. When appropriately removed, post-op IOP spikes are similar with different OVDs.

Lower viscosity dispersive OVDs are lower molecular weight and have low zero shear viscosity (less than 100,000 mPaS). The advantage of these OVDs is that they are retained better in anterior chamber during high level of fluid turbulence such as during phacoemulsification. They are capable of partitioning spaces such that there is a viscoelastic occupied space and a working space with circulating balanced salt solution, which makes lower viscosity dispersive OVDs particularly useful in managing complications. When aspirated, lower viscosity dispersive OVDs, even under low vacuum, lack internal cohesion and break apart, thus they are vacuumed out in smaller pieces, leaving most of the OVD mass behind and thus provide added endothelial protection in prolonged or difficult phaco cases.

It follows that it takes longer to completely remove dispersive OVDs from the eye at the completion of surgery, when compared to cohesive OVDs, resulting in small amounts of dispersive OVDs usually being left behind at the end of surgery, causing small IOP spikes, whereas with highly viscous cohesive OVDs, either a larger amount of OVD is left, or almost none.

Currently available dispersive OVDs in the United States include Viscoat (sodium hyaluronate 3 %, 600,000 Daltons & chondroitin sulfate 4 %, 50,000 Daltons), Ocucoat, (HPMC 2 %, 80,000 Daltons, B&L) and Cellugel (Modified HPMC 2%, 300,000 Daltons, Alcon), among many others.

Healon5 (AMO), which is 2.3 % sodium hyaluronate, is a viscoadaptive OVD with a molecular weight of 4 million Daltons (it is made up of the same hyaluronic acid chains as Healon, but differs in concentration). Viscoadaptive OVDs are different from the traditional dispersive and cohesive OVDs in that they are extremely highly viscous and cohesive under low shear conditions; at low flow phacoemulsification, they do not fracture and remain undisturbed while phacoemulsification continues. By design, they also exhibit pseudo dispersive characteristics under high shear conditions, because they begin to fracture under stress, much as a solid would. They may therefore be referred to as pseudo dispersive. Like other OVDs, complete removal of viscoadaptives is essential to reduce the risk of high post operative IOP. In the late 1990s, a systematic OVD method of usage scheme the ultimate soft shell technique was proposed with the use of viscoadaptive OVDs. It was an extension of the previous soft shell technique, but the extremely high zero shear viscosity of viscoadaptives enabled the soft shell to be performed with a viscoadaptive and balanced salt solution the ultimate low zero shear viscosity OVD, with essentially the same viscosity as water.

OVD classification has recently been modified to accommodate DisCoVisc (Alcon), the first viscous dispersive OVD. DisCoVisc is a combination of hyaluronic acid 1.6 % and chondroitin sulfate 4 %, and is a higher viscosity dispersive OVD (1.7 million Daltons). DisCoVisc possesses zero shear viscosity similar to Provisc, but is dispersive, similar to Viscoat. DisCoVisc combines the advantage of both a cohesive and a dispersive OVD. It provides dual function; space maintenance (cohesive) and superior retention (dispersive) in the same syringe.

Optimizing surgical outcomes

In order to maintain space and protect tissues, the OVD should possess high viscosity at low shear rates; but low viscosity at high shear rates is also important to permit passage through a small bore cannula. For phacoemulsification and I/A, some OVD should be retained throughout the procedure in the anterior chamber, protecting the endothelium; and for IOL implantation and movement of instruments, the OVD should possess moderate viscosity at medium shear rate.

It is hard to meet all the above requirements by a single OVD, and different newer OVDs (Healon5 viscoadaptive & pseudodispersive, DisCoVisc higher viscosity dispersive), and OVD techniques (soft shell, ultimate
soft shell) have been designed to try to achieve these apparently contrary and mutually exclusive goals. Consequently, some surgeons prefer using different OVDs during different phases of phacoemulsification surgery.

To cater to this need, several OVDs come packaged in pairs. DuoVisc is an OVD system containing Viscoat and ProVisc in U.S. Similarly, Healon D+H and Healon D+GV both provide the surgeon with a two OVD system.

In contrast, surgeons who prefer to use only one OVD during surgery may find the newer DisCoVisc, or Healon5 particularly effective. Depending on individual style, for example, a tendency towards more rigorous I/A versus a gentler, slower approach a more dispersive or a more viscous OVD may be preferred. Some surgeons prefer the higher zero shear viscosity of Healon5 and use of the ultimate soft shell technique. In all of these techniques, the common goal of devising a method to enhance OVD retention during the turbulent phases of surgery, and a second method to enable easy removal of all the OVD at the termination of surgery prevails.

There are various products in the Indian market sold under various brand names. They are Intavisc, Hyvisc, viscomet, Moisol-R are substances containing HPMC. They are marketed in prefilled syringes. Chances of contamination are much reduced. Other companies are trying to bring Healon (Hiluron) and chondroitin sulfate (Viscocel).

OVDs are essential tools in cataract surgery. The choice of best OVD is based on personal surgical technique as well as individual surgical case physical requirements. With the availability of so many OVDs possessing diverse rheological properties that influence their surgical behavior, it is tough to make a selection. Detailed knowledge of OVDs and their biomechanical properties is important in order to make the right choice.

References