Editorial

Ophthalmic Viscosurgical Devices (OVDs) Past, Present and Future

Ophthalmic viscosurgical devices (OVDs) are an integral part of the modern anterior segment surgery. Although used initially as vitreous substitute, their role came in the forefront of ophthalmology with the success of extra capsular cataract extraction (ECCE) and the use of intra ocular lens implants (IOLs). Sodium hyaluronate (Healon) was the first OVD launched by Pharmacia in 1980. However, over the years, different OVDs have been evolved with very tissue-specific role, based on their physical properties.

The OVDs are aqueous solution of naturally occurring long-chain polymers such as sodium hyaluronate, hydroxy propyl methyl cellulose and chondroitin sulphate. They are differentiated from each other by their physical properties of viscosity, elasticity, rigidity, pseudoplasticity and cohesion.

All OVDs are used to create space, to balance pressure in the anterior and posterior segment of the eye, to stabilize tissue and to protect the corneal endothelium[1].

The function of protection, cohesion, lubrication and retention of OVDs is governed by their polymer structure, molecular weight, electrical charge, purity and inter-chain molecular interaction.

OVDs act as viscous liquids as well as elastic gels. The ideal viscoelastic substance should be viscous enough to prevent collapse of anterior chamber. It should be cohesive also to be removed easily from the anterior chamber but not so cohesive that it is aspirated during irrigation and aspiration, providing no protection to the corneal endothelial cells[2].

OVDs are generally categorized into "Cohesive" and "Dispersive" groups on their rheological properties[3]. Cohesion is the tendency of the constituent molecules to adhere to one another. This property is dependable on the molecule's chain length and chemical structure. They all are pseudoplastic with high resting viscosity and high molecular weight. The pseudoplastic propertyrefers to the compounds which show greater viscosity in stationary form but exhibit decrease in viscosity when operative shear rate or force is applied. This differentiates it from true plastics (like many household objects) which always remain in solid state. Cohesive OVDs tend to stay together as a mass and come out as a single blob. They do not stay in the anterior chamber if aspirated, even when you want them to stay behind.

Dispersive OVDs have short molecular length, stay where placed and are harder to remove. They are termed as pseudoplastic when their viscosity decrease with movement e.g. Viscoat (Alcon-USA), or non-pseudoplastic showing no decrease in viscosity with increasing movement, e.g. Occu Coat (Storz-Germany).

The simple distinction between cohesive and dispersive OVDs has been intrigued by the introduction of the new generation of viscoelastic products such as: Healon 5 (AMO – USA), which displays the either properties under different environment. At slow shear rate, it appears to be extremely viscous and cohesive but at increase flow rate, its molecule breaks up, manifesting dispersive behavior. This ability of Healon 5 to change from super-viscous cohesive to pseudo-dispersive behavior is termed as viscoadaptivity[4]. Viscoadoptive OVDs have high viscosity but comfortably fractionate so are easily retained behind.

OVDs are classified in respect to their zero shear viscosity and cohesion. The zero shear viscosity is directly proportional to the molecular weight of the compound. They are broadly grouped as High Viscosity Cohesive, Lower Viscosity Dispersive, Visco-Adoptive and Visco-Dispersive or Combined Cohesive / Dispersive OVDs.

The High Viscosity Cohesive OVDs are super-viscous when these agents show extremely high zero-shear viscosity greater than 1 million mPaS (milli Pascal Seconds) e.g. Healon GV (AMO-USA). Healon GV has concentration of 1.4 % sodium hyaluronate and a molecular weight of 5 million Daltons. Its property of high cohesiveness of super viscous material results in its easy removal as a single mass at

the end of the surgical procedure, thus preventing post-operative rise in intraocular pressure. They can be viscous cohesive with viscosity between 10,000 and 1 million mPaS. The original Healon (AMO-USA) and Provisc (Alcon – USA) fall under this category. Both of these agents contain 1% sodium hyaluronate. However Healon has molecular weight of 4 million Daltons compared to 2 million Daltons of Provisc.

The Lower Viscosity Dispersive OVD **s**areagents with low molecular weight and shorter molecular chains. They can be medium viscosity dispersive with zero-shear viscosity between 10,000 and 100,000 mPaS, such as Viscoat (Alcon-USA) containing sodium hyaluronate 3% and chondroitin sulphate 4%, or very low viscosity dispersive agents including all unmodified hydroxy propyl methyl cellulose (HPMC) compounds. When injected in to the eye, these agents fragment in to small portions and disperse in to anterior chamber. They are useful in protecting corneal endothelium especially in hard cataracts when extra ultrasonic energy is used and in abnormal corneal endothelial conditions such as Fuch's endothelial dystrophy. These agents are also capable of surgical compartilization, dividing anterior chamber in to OVD-occupied space and surgical zone, in which irrigation and aspiration is taking place.

The Visco-adaptive OVD **s**are agents which change their behavior at different flow rate during phacoemulsification. Healon 5 (AMO-USA) containing 2.3% sodium hyaluronate, is specifically developed so that at lower flow rate, it behaves as very cohesive viscoelastic like Healon GV and at higher flow rate during chopping, it begins to fracture and acts similarly to a dispersive viscoelastic such as Viscoat.

Visco-dispersive or Combined Cohesive/ Dispersive OVD **s**consists of DisCoVisc (Alcon – USA) having 4% chondroitin sulphate and 1.7% sodium hyaluronate. It is a unique result of attempting to form an OVD in which zero – shear viscosity and cohesion have been dissociated and independently adjusted, combining the attributes of two OVD groups, so it has the desired viscosity of Healon, and dispersive characteristics similar to Viscoat. The chondroitin sulphate in DisCoVisc and Viscoat is very dispersive with a low viscosity and remains adhered to the corneal endothelium. The chondroitin sulphate also works better when it is mixed with sodium hyaluronate, achieving better viscosity profile.

Clinical applications of the OVDs

OVDs are commonly used during modern phacoemulsification technique for removing cataract. During Capsulorhexis high viscosity cohesive OVDs or visco-dispersive agent are used for this maneuver. They provide excellent visibility due to high transparency. They not only maintain the depth of anterior chamber (AC) but keep the pressure of AC greater than or equal to that inside the capsular bag. This provides good capsular flap control with prevention of capsular flap dragging peripherally. A lot of surgeons use low viscosity dispersive such as HPMC to carryout capsulorhexis. The reason for this is relative less cost of the compound. To maintain AC with HPMC, the entry wound has to be smaller in width or HPMC has to be injected repeatedly. When emulsifying nucleus, cohesive OVDs help to preserve the space in AC while dispersive compounds adhere to the corneal endothelium providing much needed protection against transmission of higher ultrasonic energy and mechanical trauma due to nuclear fragments. The higher viscous agents like Healon 5 also enlarge small pupils (Visco-Mydraisis) and push back iris and vitreous to neutralize positive vitreous pressure. At the beginning of all phacoemulsification cases, an appropriate period of irrigation and aspiration without ultrasound should be carried out to produce a sizable fluid cavity inside the OVD-filled AC. The dispersive OVDs take longer and their removal is enhanced by moving the phaco probe tip from side to side. The entry wound burns within seconds of starting surgery with ultrasonic energy in OVD filled AC are due to irrigation occlusion and heat generating potential of the OVDs. Floyd and co workers[5] have elegantly shown that OVDs are not only concern due to outflow occlusion but also they variably can add up to 6 times the heat creation of ultrasound in comparison to Balance salt solution (BSS). Soft Shell Technique was developed and described by Arshinoff[6] to protect corneal endothelium, when hard cataracts are emulsified using ultrasonic energy. In this technique first the lower viscosity dispersive is injected into the anterior chamber, followed by high viscosity cohesive agent injected in the center to push dispersive viscoelastic layer against the corneal endothelium. Role of viscoelastic during irrigation and aspiration is the protection of corneal endothelium. The low viscosity dispersive remains attached to the cornea while lens cortical matter is being removed. During IOL implantation it is necessary to expand the capsular bag

with a viscoelastic. It allows easy IOL rotation with correct positioning and centering.

Use of various dyes such as fluorescein sodium, indocyanine green (ICG) and trypan blue has been reported for staining the anterior lens capsule in white cataracts[7]. Akahoshi[8] proposed Soft Shell Stain technique for performing capsulorhexis in the white cataracts. This technique is identical to one described by Arshin off with difference that, after injecting high molecular dispersive and high viscosity cohesive, ICG is injected over the lens surface staining anterior capsule while cornea remains unstained. Alternatively the dye solution can be mixed with viscoelastic agent as described by Kayikicioglu and coworkers[9]. The purpose is to limit the contact of trypan blue to the corneal endothelium.

The viscoelastic agents are also mixed with the topical anesthetic solution of Lidocaine. In experimental and human studies, it has been suggested that viscoanesthetic solution with Lidocaine concentration up to 1.65% are non-toxic to corneal endothelium, uveal and retinal tissue[10, 11].

OVDs are also used to maintain AC throughout the trabeculectomy. The intracameral use of Healon 5 has been found helpful to prevent early post-operative hypotony[12]. Lopes and coworkers[13] in a prospective randomized trial used injection of balanced salt solution (BSS) or Healon 5 subconjuctivally to modulate bleb formation. There was no difference in the overall success rate; however Healon 5 was associated with more diffuse blebs. During viscocanalostomy, the Schlemm's canal is opened using high viscosity OVDs preferably Healon GV or Healon 5[14].

OVDs are used in Vitreo-retinal procedures such as macular hole repair and other vitreo retinal surgeries.

OVDs are used to maintain the AC during penetrating keratoplasty (PK) and also to expose the descement's membrane in deep anterior lamellar keratoplasty (DALK)[15].

Complications of OVDs

The use of OVDs is not without any side effects also. They can cause an increase in the intraocular pressure (IOP). The rise in IOP occurs during first 24 hours after the phacoemulsification but resolves spontaneously within 72 hours in most of the cases[16]. The increase in IOP is due to decrease in outflow facility caused by large molecules of viscoelastic material blocking the trabecular meshwork. To avoid this complication, the viscoelastic material should be thoroughly evacuated from AC at the end of the procedure. The Capsular Block or Capsular Distension Syndromeis another complication which occurs when the opening of capsulorhexis is quite smaller than the optical diameter of the IOL, with entrapment of viscoelastic material in the capsular bag[17]. This can induce pseudo-myopia in the immediate postoperative period. This condition can be easily diagnosed with slit-lamp biomicroscopy, ultrasonic biomicroscopy (UBM) and Optical coherence tomography (OCT) of the anterior segment. The Pseudo-anterior Uveitishas also been reported with the use of OVDs. This occurs because of viscous nature of OVDs and electrostatic charge of their chemical compound. It usually resolves within few days requiring no specific treatment.

OVD**s**arean integral part of the modern cataract surgery. Ophthalmologist should be aware of all different properties of different viscoelastic substances. The field of OVDs is constantly evolving and keeping abreast of all changes is in the benefit of both the patient and the physician.

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