Understanding OVDs is essential for good cataract surgery

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in London

CATARACT surgeons need to have a thorough understanding of the classification of ophthalmic viscosurgical devices (OVDs) if they are to use them to their best advantage, said Steve Arshinoff MD FRCSC in his Rayner Medal lecture at the annual meeting of the United Kingdom and Ireland Society of Cataract and Refractive Surgeons (UKISCRS) held in conjunction with the XXIV Congress of the ESCRS.

Dr Arshinoff, University of Toronto, Ontario, Canada, noted that there are now nearly 80 OVDs on the market and that their properties vary widely. In order to understand how best to use a given OVD it is necessary to understand what class it fits into and how OVDs of that class behave differently from those of other classes, he emphasised.

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Moreover, a better understanding of which properties of OVDs ophthalmologists find most advantageous can help polymer chemists and rheologists develop new devices with properties not found in available products.

"As we gradually increase our understanding of how OVDs really behave in surgery, it teaches us how to adjust the phaco machine settings for the optimal OVD behaviour of the OVD we are using, and also how to adjust our surgical technique to our OVDs. It also shows us how to make better OVDs for different surgical needs," he said.

Rheological classification

Dr Arshinoff noted that the rheological classification of OVDs is closely related to their primary functions in cataract surgery. Those functions include the maintenance and stabilisation of the anterior chamber during capsulorhexis and IOL implantation, and the protection of the endothelium during phacoemulsification, irrigation and aspiration.

Pictured from left to right are: Paul Rosen, President UKISCRS, Steve Arshinoff, Medal Recipient and Donald Munro, Managing Director, Rayner

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So, for example, the highly viscous and cohesive OVDs, like HealonGV® (AMO), are classed together in both functional and rheological terms since, as a group, they provide better anterior chamber depth and stability and are easier to remove from the eye at the end of surgery than are the lower viscosity dispersive OVDs.

On the other hand, lower viscosity dispersive OVDs, like Viscoat® (Alcon), are better as a group at remaining in the eye during phacoemulsification at high flow rates, he continued.

"High viscosity cohesives and low viscosity dispersives have very different behaviours. High viscosity cohesives create space and induce and sustain pressure. But lower viscosity dispersives have prolonged retention during phaco and they can partition spaces. Partitioning spaces into a viscoelastic protected area is what we want to do in most types of complications," he explained.

Meanwhile, viscoadaptives, like Healon5® (AMO) and iVisc Phaco® (BD Ophthalmic Systems), have good retention in the eye and also provide good anterior chamber maintenance. But they can be difficult to remove because they fracture on the edges of IOLs under high vacuum, Dr Arshinoff noted.

In rheological terms, viscoadaptives behave as if they were extremely viscous and cohesive when under conditions of lower turbulence. However, when flow increases to 10-45 cc/min they undergo a phase of change, which causes them to become almost solid and start to fracture.

"Under those conditions viscoadaptives are not dispersive but they behave like a dispersive because they follow the laws of solid physics instead of fluid physics and start to break apart," he explained.

The origins of OVDs

The history of OVDs began in 1934, when Karl Meyer and John Palmer, at Columbia University, New York, isolated a new polysaccharide from the vitreous humour of cows. They called it "hyaluronic acid" because they extracted it from the hyaloid and it contains uronic acid.

Over the following decades, Endre Balazs PhD, a Hungarian polymer chemist, perfected the techniques of extracting hyaluronic acid from rooster combs and purifying it to the point that it could be used in humans. Dr Balasz was also the first to suggest the use of hyaluronic acid in ophthalmic surgery.

The Swedish rheologists Ove Wik and Hege Bothner Wik at Pharmacia licensed Endre Balazs' new preparations of the polymer, producing Healon, the first OVD, in 1979. That same year, Robert Stegmann MD and David Miller MD carried out the first cataract surgeries using Healon in humans. Pharmacia launched their product in 1980.

As the number of new OVDs began to multiply, the Swiss ophthalmologist Georg Eisner MD began to investigate the ways different OVDs could be used in surgery. John Alpar MD meanwhile pioneered the standardisation of OVD classification and John Emes MD organised the ISO standards for OVDs.

Dr Arshinoff said that he first became involved in OVD research at the urging of Ilan Hofmann, a polymer chemist at Pharmacia, who was also a friend of his from his high school and university days. Hofmann now has a Canadian company that markets OVDs and other ophthalmic devices.

"I was at an American Academy of Ophthalmology meeting in the late 1970s and Hofmann pulled me aside into his tiny booth under a small wooden rooster and said, 'We need someone like you who likes engineering and physics, to figure out how to use this stuff'. We've been working together on and off ever since," he added.

Soft shell technique

As no OVD currently available will be adequate on its own for every eye and in every surgical situation, cataract surgeons should keep a range of OVDs ready with differing fluidic properties, Dr Arshinoff said.

"Different OVDs are best used for different things. You have to have more than one in your surgery and not just get the cheapest one you can find that will only do one thing for you and not do multiple different things," he added.

To take advantage of the varying properties of OVDs, Dr Arshinoff developed the soft-shell technique, which uses two very different viscoelastics in the same procedure, and the ultimate soft-shell technique, which uses a viscoadaptive OVD in combination with balanced salt solution (BSS).

"The idea of the soft-shell technique is to take two of the most different OVDs we could find in the marketplace, a low viscosity dispersive and a highly viscous cohesive, and use them together to achieve the benefits of all the classes of OVDs we have at the same time," he explained.

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The soft shell technique involves first injecting a mound of low viscosity dispersive OVD onto the central anterior surface of the lens and then injecting a high viscosity cohesive beneath it. As injection of the viscous cohesive progresses, it pushes the dispersive OVD upwards and outwards to form a smooth layer adjacent to the corneal endothelium.

During phacoemulsification, the phaco probe rapidly aspirates the high viscosity cohesive but leaves the dispersive OVD behind, protecting the endothelium. Following cataract removal, the capsular bag and anterior chamber are loosely filled with a high viscosity cohesive OVD, which serves to stabilise the perimeter of the anterior chamber. An injection of the dispersive OVD into the centre of the pupillary space provides a distinct lower viscosity zone through which to move the IOL.

As the dispersive OVD is fully encapsulated in a high viscosity cohesive, it is easier to remove at the end of surgery, he noted.

Soft shell variations

Variations on the soft shell technique can be very useful in some of the more complicated cataract cases, such as those with Fuchs' endothelial dystrophy, broken zonules or holes in the posterior capsule, Dr Arshinoff said.

In eyes with Fuchs' endothelial dystrophy, the main difference from the standard soft shell technique is that the dispersive agent is left in the eye to prevent damage to the already marginal endothelium. Ocular hypotensive agents, such as Carbachol 0.25 per cent drops are necessary with this technique to prevent an unacceptable postoperative spike in IOP.

In cases with broken zonules, a simple modification of the placement of the dispersive agent so that it covers the area of zonular dehiscence will protect the area throughout the procedure. Pressurising the dispersive OVD with a cohesive OVD serves to push back the bulging vitreous, further enhancing the safety of the case, he said.

A similar principle is involved in eyes where there is a small capsular hole. Isolating the hole with the dispersive viscoelastic prevents the phaco and I/A tips from drawing out the vitreous strands. In addition, subsequent pressurisation of the anterior chamber with the higher viscosity cohesive OVD moves any protruding vitreous back through the hole. A posterior capsulorhexis is then performed before proceeding.

Ultimate soft shell technique

Dr Arshinoff designed the ultimate soft-shell technique to take advantage of the versatility of viscoadaptives and at the same time get around their drawbacks. It involves using a viscoadaptive together with balanced salt solution (BSS) in the place of a low viscosity dispersive OVD, he added.

"I call it the ultimate soft shell technique not because it is the best in the world and you can't do better, but because you can use Healon5 with balanced salt solution, and water has the lowest possible viscosity of any aqueous solution, 1.0."

Viscoadaptives have the good retention properties of lower viscosity dispersive OVDs and the good anterior chamber maintenance of high viscosity cohesives,

New classes of OVDs

Up until recently, rheologists and ophthalmologists have analysed OVDs primarily in terms of their elastic and viscous properties and have not investigated their cohesive and dispersive properties separately, Dr Arshinoff said. That is because there was a 95 per cent correlation between the viscous and cohesive/dispersive properties of all the OVDs that had been developed, he explained.

However, the analysis of OVDs specifically in terms of their cohesion/dispersion properties has led to the creation of new categories of OVDs. It has also contributed to the development of DicoVisc® (Alcon), a new OVD that is both viscous and dispersive and therefore fits into none of the pre-existing OVD categories.

Dr Arshinoff noted that in 1996 he and his associates John F Poyer and Y Kwan Chan devised a method of measuring the cohesion/dispersion properties of OVDs independently of their viscosity in a way that would closely correlate with each substance's behaviour in surgery.

Their technique involved placing a phaco tip in a small beaker of viscoelastic, gradually increasing the vacuum and measuring how much came out over a period of two seconds. From that measurement they calculated the cohesion/dispersion index (CDI).

The researchers found that among the OVDs there are three different cohesion/dispersion curves. First there are the highly viscous OVDs, such as HealonGV, which remain stationary until a certain vacuum is reached and are then rapidly aspirated. Then there are the dispersives, like Viscoat, which come out gradually as a function of increasing vacuum. There are also those that were somewhere between the two, such as Provisc® (Alcon).

Dr Arshinoff and his associates also found that what made the OVDs cohesive or dispersive was the concentration and molecular weight of their hyaluronic acid component. While in dispersive OVDs the hyaluronic acid has a low molecular weight and is at a high concentration, in cohesive OVDs it has a high molecular weight and is at a low concentration.

"Molecular chains tend to entwine, and longer chains make the entire solution move together as a mass. The more concentrated the molecular chains, the smaller the space filled by each intra-chain and inter-chain entanglement."

A viscous dispersive OVD

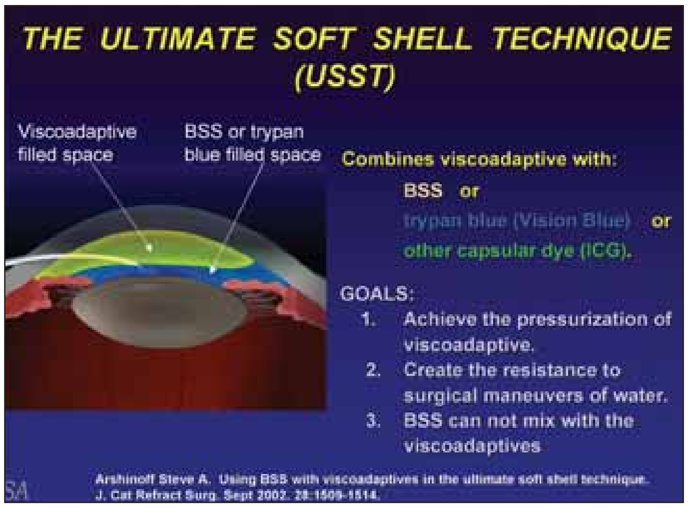
Building on these findings, Masoud Jaffari PhD and his associates at Alcon laboratories developed DisCoVisc, a viscous dispersive OVD. DisCoVisc has the same concentration of chondroitin sulphate as Viscoat but has a lower concentration of hyaluronic acid at a higher molecular weight.

As a result, the new OVD behaves like a high viscosity cohesive while stationary, but like a low-viscosity dispersive at higher shear rates. In addition, its CDI is much closer to that of Viscoat than it is to that of a high viscosity cohesive.

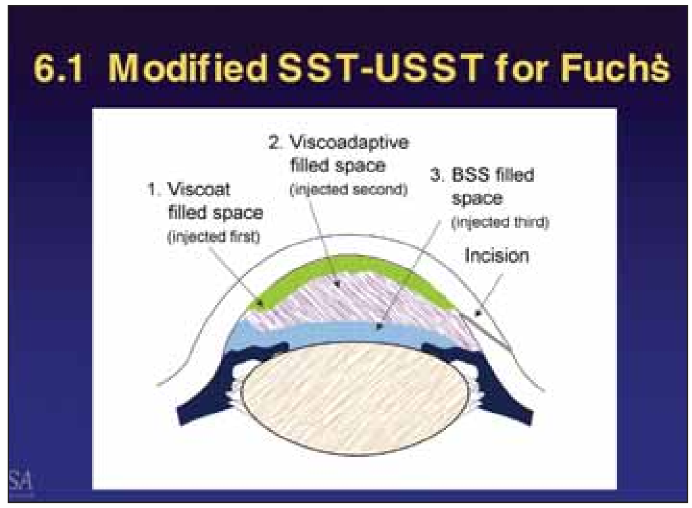
The properties of DisCoVisc therefore afford the cataract surgeon with better anterior chamber maintenance than the lower viscosity dispersive OVDs and also provide better retention within the eye during phaco at high flow rates than the higher viscosity cohesive OVDs.

In addition, the device provides better endothelial cell protection during phaco than a higher viscosity dispersive OVD, but is easier to remove from the eye at the conclusion of surgery than a lower viscosity dispersive.

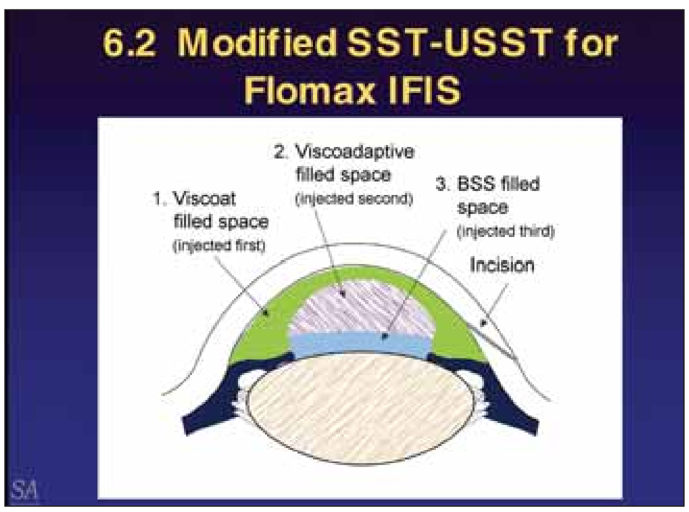
He added that the disassociation of viscosity from cohesion and dispersion has created three new categories of OVDs. DisCoVisc occupies one of the new categories, the viscous dispersives. But there remain two new categories, low viscosity cohesives and very high viscosity dispersives in which there are currently no OVDs.



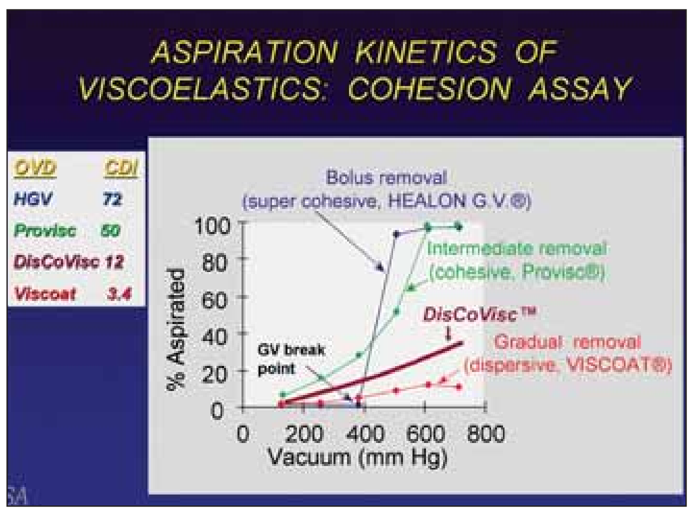
USST – precapsulorhexis step



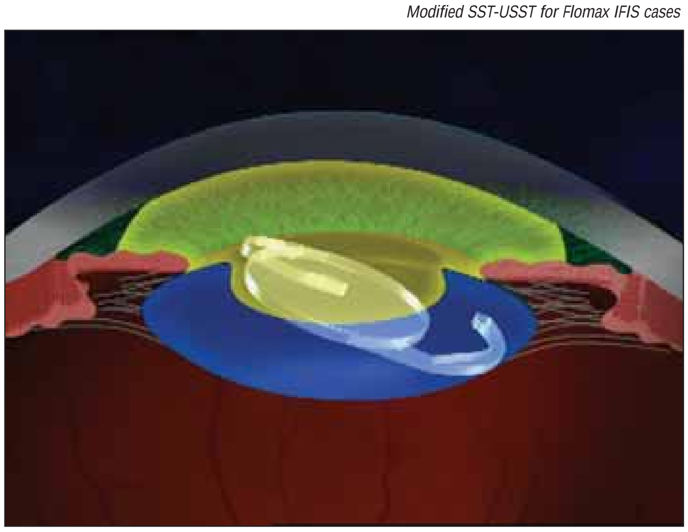
Modified SST-USST for Fuchs'

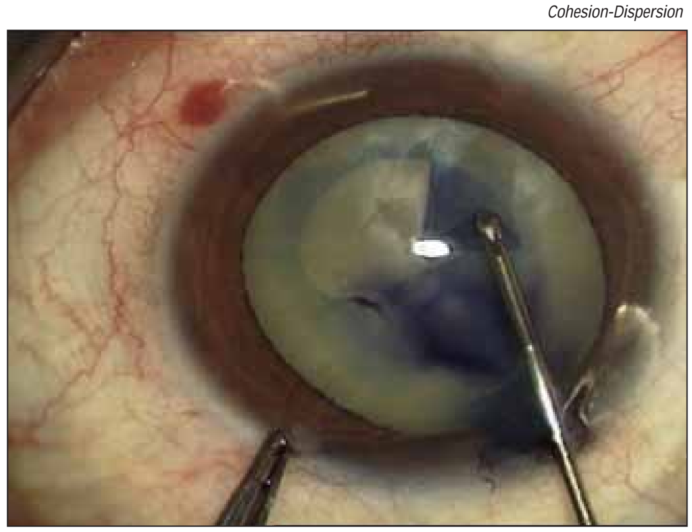


Modified SST-USST for Flomax IFIS cases



Cohesion-Dispersion


Implanting the IOL


USST capsular dye technique

Courtesy of Steve Arshinoff MD FRCSC

but there are a few things in cataract surgery that they make more difficult.

He pointed out, for instance, that they are too viscous to be used easily on their own while performing capsulorhexis. In addition, they can be difficult to remove from behind an implanted IOL because they fracture at the edges of the lens, he said.

In the ultimate soft shell technique, the surgeon first fills the anterior chamber to around 75 per cent of its capacity with the viscoadaptive OVD and then injects BSS over the surface of the lens capsule. Under these conditions, the viscoadaptive blockades the incision, which, in turn pressurises the anterior chamber, and the BSS provides a low viscosity environment for the capsulorhexis.

"Performing a capsulorhexis becomes much easier in a pressurised, but low viscosity environment," he said.

Following cataract removal and prior to IOL implantation, the anterior chamber is filled with the viscoadaptive OVD, which is injected across the capsulorhexis, thereby blockading it. The capsular bag is then filled with BSS, creating a pressurised aqueous environment through which an IOL can be easily placed and positioned.

"At the end of surgery there is no difficulty in removing the viscoadaptive from behind the lens because there is none to remove," he added.

Dr Arshinoff noted that the soft shell and ultimate soft shell technique can be combined into three-layered techniques for cases with Fuchs' dystrophy and intraoperative floppy iris syndrome (IFIS) seen with Flomax administration.

The technique basically involves using a viscoadaptive in the place of a high viscosity cohesive in a standard soft shell technique, but also injecting a thin layer of water on the surface of the capsule, under the OVDs, prior to performing a capsulorhexis.

In Fuchs' dystrophy, the use of a low viscosity dispersive OVD in this approach provides the endothelium with an added degree of protection. In intraoperative floppy iris syndrome, the presence of a high viscosity OVD helps to dilate the pupil, while the peripherally located dispersive OVD tamponades iris flopping.

OVDs and IOP

When Healon was first marketed, reports began to emerge that its use was associated with severe postoperative intraocular pressure spikes that were difficult to treat. In fact, severe IOP spikes caused several patients to lose significant amounts of their vision before cataract surgeons understood the necessity and techniques for OVD removal, Dr Arshinoff said.

Since that time, many companies have claimed that their products entail less risk of dangerous IOP spikes than other OVDs. However, several studies have established that, so long as the OVD is completely removed from the eye at the end of surgery, the type of OVD employed has no bearing on postoperative IOP.

The studies indicated that the severity of a postoperative IOP spike instead depends on other aspects of the individual surgeon's technique or on factors related to the individual patient's eye.

He noted, for example, that in a contralateral eye study he and his associates conducted (Arshinoff SA et al, JCRS, April, 2002) there was no significant difference between Healon, Healon GV or Healon5 in terms of postoperative IOP. The study involved 99 patients who underwent bilateral cataract surgery with a different OVD in each eye.

"All patient groups showed a small IOP spike at five and 24 hours, but there were no significant differences in the severity of the IOP spikes among the viscoelastics. In addition, patients who experienced a severe spike in one eye, usually experienced a similar spike in the other eye, using a different viscoelastic," he said.

"The design of OVD fluids and the techniques to use them is limited only by our imagination and creativity"

Confirmation of those findings comes from two further studies by Abhay Vasavada and his associates *(Vasavada AR et al, JCRS 2004. 30: 1; 137-143)*. The studies showed that the severity of the IOP spike after the phacoemulsification of very dense cataracts was proportional to the phaco time and power of the procedure. They also showed that using straight flare phaco tips, which deliver more energy to the trabecular area, result in higher IOP spikes than occur with Kelman tips, which aim the ultrasound energy more posteriorly.

Management of IOP spikes when they occur is best achieved by first draining the aqueous three times at hourly intervals and treating with cholinergics and/or prostaglandin analogues. Aqueous production reducing agents, such as Alpha 2 adrenergic agonists, carbonic anhydrase inhibitors, and beta-blockers should not be used in such cases because they only delay the washout of the OVD, and have no ability to reduce IOP in these cases, he advised.

Dr Arshinoff reiterated that OVDs should be classified according to the parameters most significant in surgery. He also recommended that companies that manufacture OVDs provide instructions on the methods for using new OVDs when they become available.

"The design of OVD fluids and the techniques to use them is limited only by our imagination and creativity," he said.

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Early days of Healon

It is hard to imagine eye surgery today without Healon and other OVDs at the ready. Before Healon became available, surgeons' only options were air or saline, neither of which worked very well. The result was less than perfect visual outcomes attributable to corneal endothelial cell loss.

"The arrival of IOLs created a demand for something to protect the endothelium. You had to slip the IOL into a moderately large incision. When you made the incision the eye would collapse and vitreous would flow out. It was really very difficult not to brush the back of the cornea, and the plastic the IOLs were made of was hydrophobic, so they tended to attract the endothelial cells. This was a prescription for disaster and many surgeons had a lot of trouble. It was clear we needed a lubricant," recalled David Miller MD, Harvard University Medical School, an early OVD pioneer.

Dr Miller had been tennis partners with Endre Balazs PhD, the man who patented a method for purifying hyaluronic acid from rooster combs. Dr Miller noted that Dr Balazs would test the purity of his early batches of hyaluronic acid by injecting it into the knee joints of test animals. A contaminated batch would produce inflammation. However, Dr Balazs also noticed that a pure batch appeared to help reduce inflammation in animals with traumatic short-term arthritis. So he initially convinced Pharmacia there might be a market in equine arthritis.

Dr Balazs collaborated with Pharmacia to develop the product now known as Healon. While Dr Balazs had originally thought the product might have potential in the orthopaedic side of medicine, Dr Miller suggested to him that it might be quite useful in ophthalmology.

Dr Miller conducted a series of animal experiments the results of which encouraged him to test it in a couple of patients. "It was just what we were looking for. You pump it into the eye, it stays there, it doesn't leak out, it's clear, and non-toxic. In addition to acting as a lubricant, it expanded the anterior chamber, keeping the eye round. This made it much easier to put in the IOLs," Dr Miller told *EuroTimes*.

Robert Stegmann MD was Dr Miller's first Fellow at Harvard. Dr Stegmann carried out the first major clinical trial with Healon at his hospital in South Africa. That study compared Healon vs. saline in terms of their effects on corneal clarity and endothelial cell counts. Dr Stegmann presented the results, which strongly favoured Healon, in 1979 at a conference in Cannes.

Dr Miller noted that Healon was quickly accepted by most in the eye surgery community, noting that it did not encounter the kind of resistance seen after Charles Kelman introduced phacoemulsification or when Harold Ridley introduced the idea of intraocular lens surgery. "Surgeons were quick to see the benefits of using Healon. All someone had to do was try it to realise how much easier cataract surgery was when using Healon," he said.

Together with Dr Stegmann, Dr Miller authored the book *Healon (sodium hyaluronate): A Guide to its Use in Ophthalmic Surgery, (A Wiley)*. Dr Stegmann told *EuroTimes* that the introduction of Healon came at a critical time in the history of IOLs. There was at that time a moratorium on IOLs in two states in the US and a measure was before congress to ban IOLs nationally. Were it not for the introduction of viscoelastics, IOL technology could have been held back for decades, he said.

"IOLs could have died. There was a tremendous amount of resistance to IOLs. All the established chairs of ophthalmology in Europe had condemned these things as tools of the devil," he noted.

Dr Stegmann had been working with Dr Miller from 1972 and it was one particular case in late 1976 that brought home to the two surgeons the urgent need for a substance that would protect the endothelium and other intraocular structures during cataract surgery, he noted.

They had completed what seemed to be a very ordinary IOL implantation and everything had apparently gone to plan. However, the next day the cornea was white and completely opaque.

"With very judicious use of steroids and a lot of prayers the case turned around in a few weeks and the patient was fine but we both said, 'hey, wait a minute this is as dangerous as everyone is making out.' We resolved at that point to find some way to prevent this sort of thing from happening," Dr Stegmann said.

Over the succeeding months they tried and tested various substances that were available at the time but none of them worked. Dr Miller recalled the work of Dr Balasz with sodium hyaluronate, when both of them worked at Massachusetts eye and ear infirmary. Dr Balasz had been investigating the potential use of the substance as a vitreous replacement.

The results of the vitreous replacement experiments had proved disappointing, however, as the substance produced inflammation when used in that way. When Drs Stegmann and Miller approached Dr Balasz they found he had little enthusiasm for the idea of using sodium hyaluronate in cataract surgery.

"Balasz had taken quite a battering from all the bad press of the vitreous replacement. He was very reluctant to get involved and wouldn't give me any sodium hyaluronate to experiment with. But after a couple of years I twisted his arm in a pub to give me six ampoules which I took back to Boston and did rabbit surgery and the results were absolutely remarkable."

On the strength of these findings Dr Stegmann was able to persuade a still doubtful Pharmacia to fund a controlled trial of the substance in 40 eyes of 20 patients at a hospital in South Africa. The results of the trial largely mirrored those of the rabbit eye studies. In the sodium hyaluronate group the rate of corneal endothelial cell loss was only nine per cent, compared to 45 per cent in the classic air bubble group.

"Those results were extremely well received and things went from strength to strength after that. From that time on there was money to develop new improved designs of lenses and improved surgical techniques. Without Healon you could never have thought about putting an intraocular lens in the bag with a collapsed chamber; there was no way you could ever have made a circular capsulorhexis."

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