If IOL injection is a precondition to reducing incision size and limiting surgically induced astigmatism, use of a preloaded IOL could have several potential benefits. However, the definition of preloading is ambiguous, and in practice partial automation is limited to the surgeon no longer handling the IOL.

Although we are a long way from push-and-go injection systems, certain products are getting close. Today, there are two types of preloaded injectors. The first type includes injectors that fold the IOL and place the implant in a single step, like the AcrySert C (Alcon), EyeCee NZ1 (Croma Pharma), Micro 123 (PhysIOL), and Genium (LCA). These designs have a flat load and a rigid plunger, and they are well suited to IOLs with C-loop haptics. However, today their use is limited to incisions of no less than 2.0 mm. The second type of injector requires a folding step prior to placement. These include the Isert (Hoya), Bluemix 180 (Carl Zeiss Meditec), Accuject Pro (Medicel), and Artis PL (Cristalens). With these injectors, loading is performed laterally, and the plunger has a flexible tip. They are well suited for IOLs with four-loop haptic designs and are compatible with microincision cataract surgery (MICS).

Motorized injection is another aspect of automation that can further enhance surgical performance and safety. It is possible that it may be combined with preloading in the future.

FACTORS LIMITING THE USE OF PRELOADED INJECTION

Preloaded injectors improve mechanical reliability, microbiologic safety, and the reproducibility and speed of the injection process. However, two factors limit the generalization of the preloading concept: economics and mechanical reliability.

Economically, preloaded injectors represent a significant additional cost for companies that cannot be passed on to their clients. Also, there are countless patents on injectors, and the manufacturing process is complex.

Mechanical reliability during automated folding and injection of IOLs has improved, but the use of plastic parts and the simultaneous storage of the lens and injector make it difficult to achieve consistent reproducibility. Additionally, the gliding ability of these cartridges represents a major challenge to injection, particularly for MICS. Current cartridges are most frequently made of polypropylene, which can cause friction with the IOL—especially with hydrophobic acrylic materials—if there is no buffer between them.

MINIMIZE FRICTION, IMPROVE GLIDING ABILITY

For any injection system, friction is the enemy. With minimal friction, the thrust force is moderate and the IOL advances easily, smoothly, and safely; however, with maximal friction, the thrust force becomes excessive, causing the IOL to stick against the wall of the injector and the IOL material to compress. Excessive pressure may cause the cartridge to rupture or damage the preloaded cartridge. If rupture occurs, stress is immediately transmitted to the incision and to the IOL.

There are three options to reduce friction. The most common is inclusion of a gliding agent in the polypropylene, which appears on the surface of the cartridge after sterilization. Implementation of this option is relatively easy, but the agent can be visibly deposited onto the surface of the IOL.

There are three options to reduce friction. The most common is inclusion of a gliding agent in the polypropylene, which appears on the surface of the cartridge after sterilization. Implementation of this option is relatively easy, but the agent can be visibly deposited onto the surface of the IOL. These cartridges are usually sterilized with ethylene oxide, but, when used with IOLs made of hydrophilic acrylic materials, they must be sterilized with steam in order to reduce the risk of glyceride monomers or the gliding agent being released into the storage fluid. This phenomenon has been mentioned in relation to toxic anterior segment syndrome, although the mechanism has not been elucidated. A second option is a surface-coating treatment, such as hydrophilic or hydrophobic polyvinylpyrrolidone, and a third option is the use of a plasma technology that changes the surface properties of the material. Improved gliding capability can limit mechanical stress on the plunger, improve safety, facilitate injection, and allow a reduction in incision size.

In addition to increasing the gliding capability of the injector itself, there are two additional ways to improve IOL gliding ability during injection: (1) use of an ophthalmic vis-
cosurgical device (OVD) to lubricate the injection cartridge and (2) viscoinjection, whereby an OVD is used to push the IOL into the cartridge. The best lubricating OVDs are those with low contact angles (less than 65°), such as hydroxypropylmethylcellulose; however, if the cartridge has good gliding capacity, it does not matter which OVD is used. With viscoinjection, the OVD remains in front of the IOL to facilitate gliding and reduce the pressure required to advance the plunger. Injectors that use this mechanism of action include the Accuject, Bluemix 180, Micro 123, and Artis PL.

Another obstacle to the generalization of preloaded injectors is the required incision size, which historically is about 3.0 mm. The internal diameter of the injector tunnel must be 1.6 mm for a 2.2-mm incision, 1.25 mm for a 1.8-mm incision, and at most 1.0 mm for a 1.4-mm incision, but the optic diameter of most IOLs is 6.0 mm. This gives you an idea of the mechanical stresses exerted on the walls of the injection tunnel during placement of the implant. The bevel values may reach 15 N. The cornea is not flexible, and its deformation should not exceed 15% to avoid irreversible stretching, instability, and induced astigmatism. It is always preferable to enlarge the incision rather than to cause trauma. It is even more desirable to find out the exact dimensions of the cartridge and its capacity.

### Recent Improvements

Many improvements have been made to increase the microbiologic safety and performance of preloaded injectors. First, there have been numerous changes to cartridge materials, including the use of polyimide, the improvement of covering fluids, and the incorporation of surface or plasma treat-
ments to replace gliding agents. Second, there have been several changes to sterilization methods. Third, the majority of preloaded injectors are now compatible with MICS.

Newer MICS-compatible designs are also available. The Isert and the Artis PL require the surgeon to fold the IOL, thus allowing injection through a microincision. With the AcrySert C, several features were changed simultaneously to improve performance and reproducibility. Also, certain preloaded injectors including the Accuject allow injection of IOLs made of hydrophilic and hydrophobic acrylic materials. This product uses the viscoinjection principle and includes a silicone deformable plunger tip. The loading chamber, equipped with sealing fins, is large enough to accommodate a variety of IOLs, and the injection tunnel is tough enough for most lenses. In its hydrophilic version, the loading chamber is kept in a separate moist container, and the injection tunnel and the body are dry. In its hydrophobic acrylic version, the whole device is kept dry. The MDJ preloaded injector (MDJ) includes an appendage for folding a hydrophobic or hydrophilic IOL in the loading chamber, which is then withdrawn before injection.

INJECTORS FOR HYDROPHOBIC ACRYLICS

Below is an overview of the injectors for hydrophobic acrylic IOLs that we have experience with.

AcrySert C. This preloaded injector (Alcon) allows one-handed manual injection of the AcrySof IOL, freeing the surgeon's second hand to stabilize the eye and position the IOL. The first version of this injector, the AcrySert B, was reliable but required an incision size of 3.2 mm. The AcrySert C is compatible with a 2.2-mm incision without a bevel and 2.6 to 2.8 mm if inserted into the anterior chamber. It requires a three-step technique (See Injection Steps for Hydrophobic Acrylic IOLs; Figure 1).

If the injection is performed in the anterior chamber with an incision of 2.6 or 2.8 mm, the IOL is released directly into the capsular bag. If used with a 2.2-mm incision, I use a wound-assisted technique:

1. Create the 2.2-mm incision;
2. Pressurize the anterior chamber with an OVD;
3. Fill the loading chamber with an OVD up to the mark;
4. Remove the tab blocking the IOL from right to left;
5. Push the IOL slowly with your palm on the plunger up to the mark;
6. Apply the bevel firmly at the edge;
7. With a manipulator, exert counter-pressure through the service incision;
8. Inject slowly, firmly, and without stopping;
9. Push the plunger until it stops; and
10. Position the IOL with a second instrument.
Isert. The Isert 251 is a preloaded injector designed for the NY 60 IOL (Hoya), and the Isert 250 is designed for the company’s nontinted IOL models. The injector comes with a base and includes a plunger, two sliders, a safety release, and a flange. There are four main steps for injection (See Injection Steps for Hydrophobic Acrylic IOLs; Figure 2).

Because of the cleft at the end of the injection tunnel, which is designed to control release of the IOL, the injector should not be used with a wound-assisted technique. A version for the toric IOL (Isert 351) is also available.

Artis PL. This injector, designed for the Artis one-piece IOL (Cristalens), consists of a cartridge with wings that contains the implant and an IOL-blocking system. There are five steps for injection (See Injection Steps for Hydrophobic Acrylic IOLs; Figure 3).

HPI Injector. The HPI Injector (Aaren Scientific) has the same characteristics as the Isert and is designed to inject the NC1 one-piece hydrophobic acrylic IOL (Aaren Scientific).

ITec Injector. This injector (Abbott Medical Optics Inc.) is marketed for incision sizes between 2.2 and 2.4 mm and is designed for the monofocal, multifocal, and toric Tecnis IOL models (Abbott Medical Optics Inc.). The recommended injection steps are described in Injection Steps for Hydrophobic Acrylic IOLs.

EyeCee NZ 1. The EyeCee NZ 1 is one of the rare injectors designed for a three-piece IOL made of hydrophobic acrylic material. It comes as a single unit including the injector, the IOL, and a stabilization system at the end of the injection tunnel. Four steps are required for its use (See Injection Steps for Hydrophobic Acrylic IOLs; Figure 4).

INJECTORS FOR HYDROPHILIC ACRYLICS

Bluemixs 180. The Bluemixs 180 is designed to inject the CT Asphina 509MP and 409 MP IOLs (Carl Zeiss Meditec), lenses with negative and neutral aspheric designs, respectively, and the AT LISA/AT LISA Toric and AT Torbi IOLs (Carl Zeiss Meditec). There are five steps for injection (See Injection Steps for Hydrophilic Acrylic IOLs; Figure 5).

The injector is compatible with 2.2-mm incisions by inserting the bevel into the anterior chamber and 1.8-mm incisions with a wound-assisted technique.

Micro 123. The cartridge and IOL are stored in a container in a humid environment, and the body of the injector, including the plunger and the deformable tip, are kept dry. It is designed to inject the Micro AY IOL (PhysIOL), and there are four injection steps (See Injection Steps for Hydrophilic Acrylic IOLs; Figure 6).

The Micro 123 injector can be used with a 2.2-mm incision if it is introduced into the anterior chamber and 1.8-mm if it is kept at the edge.

Genium and Genium micro. As the smallest injec-
tors currently available, the cartridge and body of the Genium and Genium micro injector are one unit, thus reducing the overall volume. The thrusting and folding systems are also one unit (a plunger-folder). Additionally, the injector, made entirely of polypropylene, has three zones. The storage zone has a flat posterior section to hold the implant; the conical folding zone is responsible for folding the IOL when the plunger is pushed; and the injection zone, designed to deliver the IOL into the capsular bag, is equipped with a beveled end to facilitate its insertion through the incision.

The plunger tip is bifurcated, allowing easy handling and guidance of the IOL from the loading chamber into the injection tunnel. Its rigidity along the axis of injection and flexibility along the perpendicular axis allow optimal thrust and a reduction in volume in the injection tunnel. During injection, the two tips join in the injection tunnel while the implant is folded. It can then be introduced into the anterior chamber.

The lateral surfaces of the injector result in flat injection in every case, and the IOL is delivered into the capsular bag without any rotation. Three steps are required for injection (See Injection Steps for Hydrophilic Acrylic IOLs; Figure 7).

**MOTORIZED INJECTIONS**

With preloaded injectors, the surgeon must manage injection control (i.e., how fast the plunger advances). A large amount of energy builds up in the injector during folding and when the IOL passes from the loading chamber into the injection tunnel and anterior chamber. IOLs made of hydrophobic acrylic material, especially higher-power lenses, generate more friction on the injector walls and contribute to an increase in mechanical stress. In certain cases, the bevel pressure may increase to 15 N before collapsing when the IOL is released. In others, the IOL can be injected outside the eye or shoot like a dart into the anterior chamber.

The Intrepid Autosert (Alcon) is a one-handed motorized injector allowing consistent and preset speed for advancing the plunger, regardless of counter-pressure. As a result, the advancement of the IOL is completely controlled until its release into the anterior chamber. The IOL cartridge is positioned within the housing. Three parameters are chosen by the surgeon (Figure 8): the initial speed of the plunger, the length of the pause that allows the IOL material to deform prior to injection, and the final injection speed.

The benefits of this system include automatic positioning of the preinjection, an adjustable and fixed speed,
adjustable duration of the preinjection pause, complete speed control, and a free hand to stabilize the eye and position the IOL. This is particularly useful for two-handed injections using a wound-assisted technique. Compared with manual IOL injectors, the consistent injection speed avoids blockage of the IOL in the incision.

Comparing motorized and manual injectors, Allen demonstrated better incision preservation with the motorized device and significantly less stretch when a rapid final speed (4 mm/sec) was used.

CONCLUSION
Preloaded injectors represent a step toward safe and rapid IOL injection, and recent advances have increased the safety, reliability, and reproducibility of these procedures and maintained incision sizes similar to those required with manually loaded injectors. There are, however, some pitfalls, and surgeons must follow the manufacturer’s instructions carefully. Motorized injectors hold promise for additional benefits as they become more widely available.

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