White Paper

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A New Approach to Internal Limiting Membrane Peeling: FINESSE® SHARKSKIN™ ILM Forceps

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Internal Limiting Membrane

The internal limiting membrane (ILM) is the basement membrane between the vitreous and the retina and stains positive with periodic acid schiff (PAS).[1,2] The inner surface towards the vitreous is smooth while the outer retinal surface is irregular and in close apposition to the plasma membrane of Müller cells. The ILM is thickest posteriorly, in the parafoveal and peripapillary regions.[2] In certain pathologies that involve the vitreomacular interface, the ILM can provide support for the proliferation of contractile cells, which are translated to tractional forces on the neuroretina.[1,3] Together with the propensity to increase in thickness with age, the elimination of the ILM in order to alleviate the tractional forces on the macula becomes necessary.[3]

ILM peeling offers several advantages, such as:[4]

- Reduction of recurrence rates of epiretinal membrane (ERM) by removing the scaffold for recurrent ERM formation
- Increased likelihood of macula hole closure and decrease in reopening rates
- Increased likelihood of complete removal of ERM and/or residual posterior vitreous cortex

Internal Limiting Membrane Peeling

Today, ILM peeling has become a common surgical procedure for vitreoretinal surgeons and is applied in cases of macular holes and other vitreoretinal diseases.

Common Indications for Internal Limiting Membrane Peeling[2,3]
1. Macular Hole Repair
2. Macular Thickness Reduction in Diabetic Macular Edema
3. Epiretinal Membrane Removal
4. Myopic Macular Retinoschisis
5. Retinal Vein Occlusion
6. Vitreomacular Traction Syndrome

Table 1: Common Indications for Internal Limiting Membrane Peeling[2,3]

Several techniques using various micro-surgical instruments with the aid of vital dyes have been introduced and utilized through time; all of which are preceded by pars plana vitrectomy. Common to all these techniques is the first step of creating an ILM flap. The creation of the flap can be accomplished by either using a sharp instrument (e.g. pick forceps, MVR blade bent with a bent tip) or by using a pair of vitreoretinal forceps designed specifically for ILM peeling. The surgeon then grasps the flap and completes the peel in a circular motion parallel to the retinal surface, similar to capsulorrhexis.[2,3]

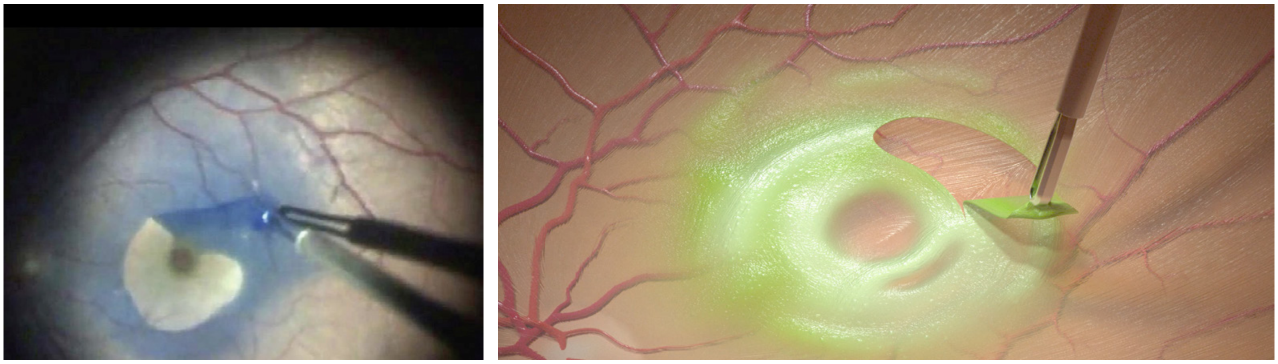


Figure 1: ILM peeling with the aid of a vital dye to stain the membrane[3] – left: ILM peeling during surgery with vital dye; right: illustrated depiction of ILM peeling with dye

Multifocal IOLs

As with other commonly performed surgical techniques, ILM peeling is associated with potential complications (Table 2).[3] For that reason, successful peeling of the ILM is dependent on a combination of surgical skills and instrumentation. This provides an opportunity for innovating new microsurgical instruments which can improve the technique for ILM peeling.

Complications Associated with ILM Peeling[3]
1. Chromophore Toxicity
2. Damage to Müller Cells
3. Paracentral Retinal Holes
4. Dissociated Optic Nerve Fiber Layer
5. Phototoxic Damage

Table 2: Complications Associated with ILM Peeling[3]

New Innovation for Peeling the Internal Limiting Membrane

As mentioned earlier, there are two common techniques to create the initial flap necessary for ILM peeling. Whether the flap is created by using a pick or by using a pair of forceps is a matter of surgeon preference. After consulting with vitreoretinal surgeons who prefer the latter technique, referred to as "pinch peeling", engineers identified two opportunities for innovation towards ILM peeling: 1) the need for improved grasping of the membrane, especially initial grasping to create an edge in the ILM, and 2) the need for minimizing the amount of pressure applied to the retina.

In the pinch peel technique, the surgeon pushes the prongs of the open forceps a few microns against the retina and then opposes the tips to grasp a portion of the ILM to create the initial flap, while skillfully applying just the right amount of force to avoid inadvertent trauma to the underlying neuroretina. The step is quite delicate, such that repeated grasping and/or applying excessive force has been known to result in nerve fiber layer trauma, resulting in paracentral scotomata and reduced vision.[4]

Since the optimal amount of force needed to perform this maneuver is difficult to judge, forceps have been designed to increase the friction between the instrument and the ILM while reducing the force required when using existing forceps (Figure 2). The innovative design in these forceps allow the mitigation of the challenges inherent to the pinch peel technique. Currently, the most preferred ILM forceps are the GRIESHABER REVOLUTION® DSP ILM Forceps (Figure 3).[1,3]

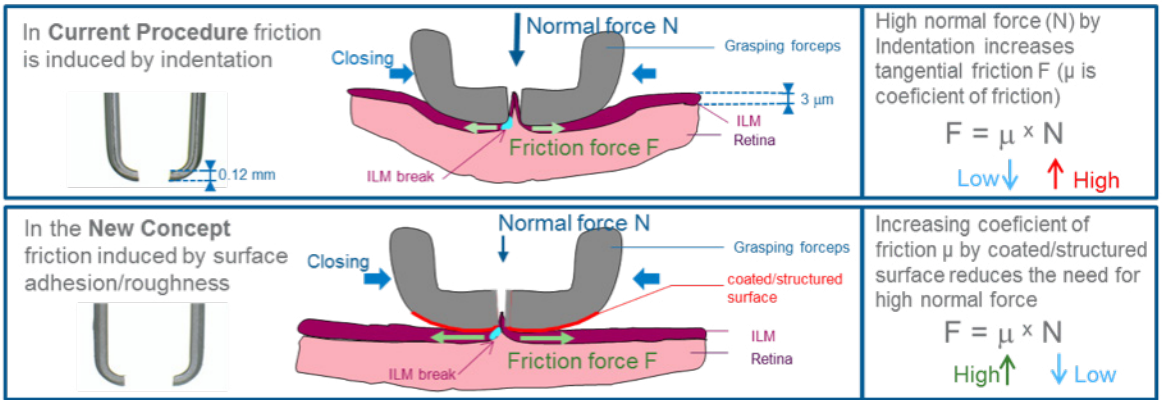


Figure 2: New forceps hypothesis is to significantly reduce or eliminate need for normal force to accomplish grasping.

Figure 3: Alcon GRIESHABER® 25 Ga ILM forceps

There are two approaches which can be taken in creating new forceps which facilitate grasping of the ILM. The first approach is to create a coated surface on the grasping tips of forceps. The second is to modify the surface structure of the grasping tips. Studies have shown that all surface coating resulted in the deterioration of force (e.g. diamond dusting). In contrast, a laser ablated microstructure proved promising and resulted in nearly a two-fold increase of the grasping ability of the forceps, as shown in force measurements[7] (Figure 4).

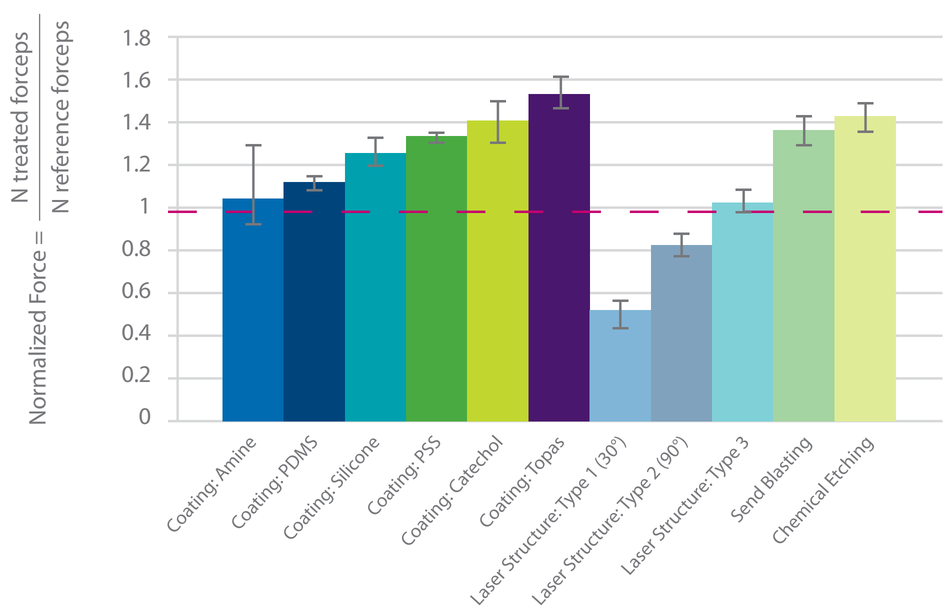


Figure 4: Measurement of normalized force for different forceps designs.

In clinical studies, a specific pattern of 10 x 10 x 5 micron teeth (created on the forceps surface by laser ablation) pointed towards the grasping edge at 30 degrees (as shown in Figure 5), was superior to the reference forceps as well as to all other surface modifications (Figure 4).

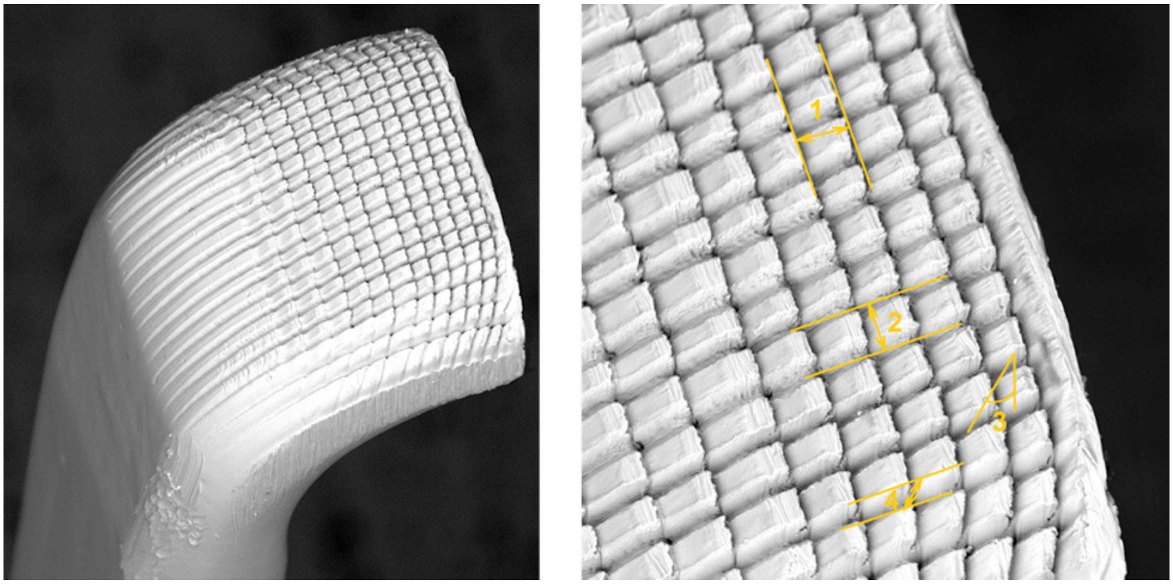


Figure 5: 23/25 Ga. Scanning electrom microscope (SEM) picture of the laser ablated microstructure. Numbers in the right photo denote geometry of the teeth: 1 - 10 µm, 2 - 10 µm, 3 - 30º, 4 -5 µm

In the concept evaluation phase for the new forceps design, the minimum force required to grasp a model membrane was measured. A rabbit lens capsule, including the rabbit lens, was used as a test model during this evaluation. The minimum force necessary to grasp the rabbit lens capsule was evaluated with the laser structured ILM forceps and compared to unstructured ILM forceps. The forceps were mounted on a lab setup that recorded force. Although the laser structured forceps showed a lower force than the unstructured one, the test results were highly variable due to the nature of the rabbit lens. Unstructured forceps had average force of 130.0 mg while laser structured forceps had statistically lower force of 79.3 mg ($p<.0001$) with a sample size of 27 tests per arm.[8]

The new forceps concept was trademarked as SHARKSKIN™ and compared to the current market leader, GRIESHABER REVOLUTION® DSP ILM forceps (Figure 6). To further confirm the advantage of the SHARKSKIN™ forceps, tribological friction measuring tests were performed.

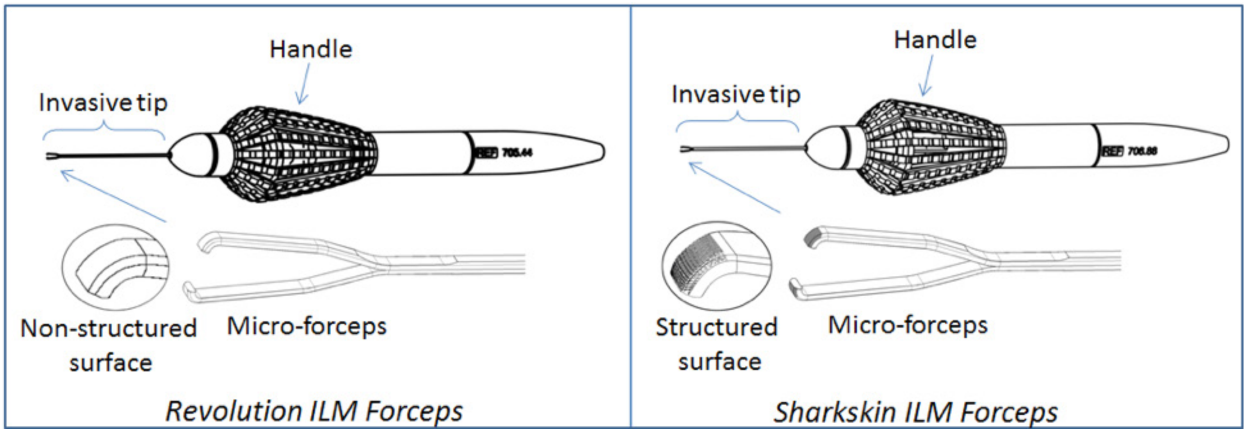
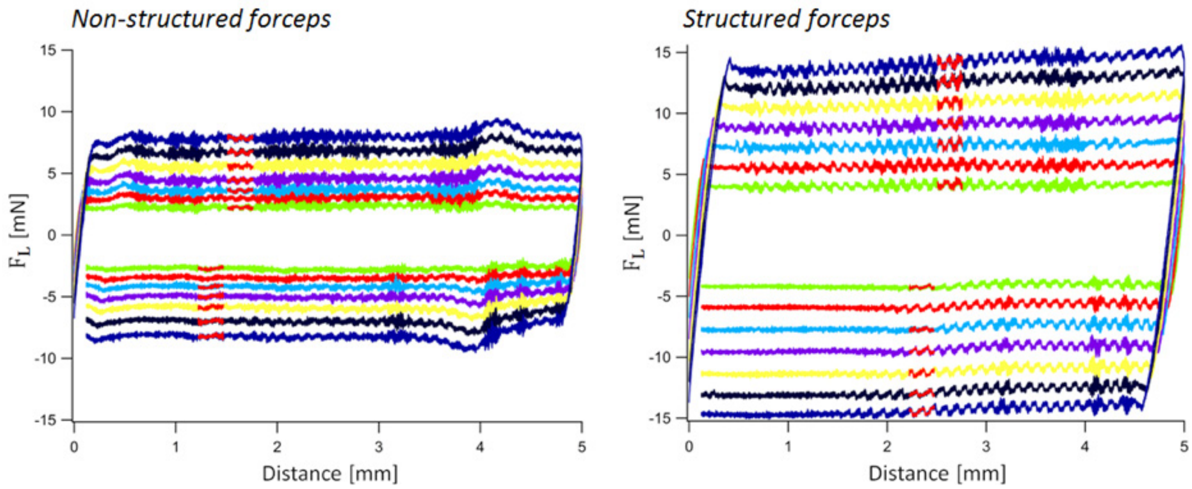


Figure 6: Reference GRIESHABER REVOLUTION® and SHARKSKIN™ ILM forceps with structured surface were tested for friction on contact lens and rabbit eye lens as models

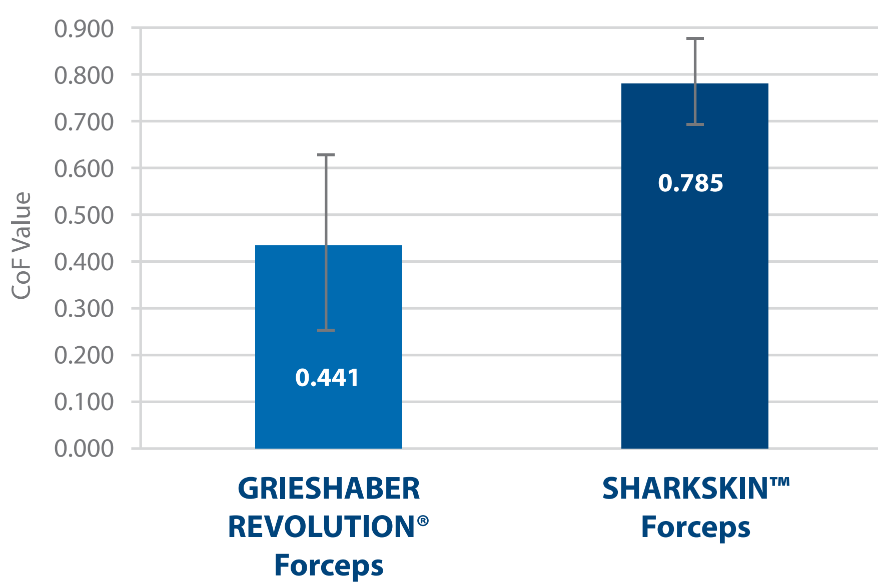
Grasping and Friction Testing in Different Membrane Models[8,9]

In order to test grasp force, three different test models were considered - AIR OPTIX® Aqua (AOA) contact lenses, rabbit eye cornea and rabbit eye lens capsule. The rabbit eye lens capsule model was highly variable in the grasping test. However, the contact lens and rabbit eye cornea models both showed highly consistent results, in which the SHARKSKIN™ ILM Forceps had a superior friction coefficient (Figure 7, 8 and 9).



AIR OPTIX® Contact Lenses was used as a model. Positive force values stand for one sliding direction, negative values for opposite direction. Different colors indicate different normal forces 23/25 Ga.

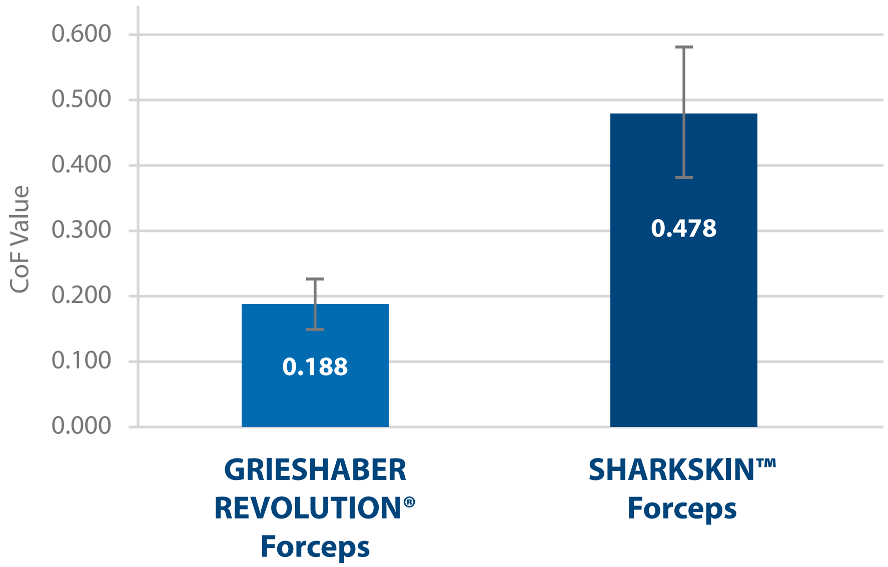
Figure 7: Examples of friction force measurements (lateral force FL vs. Distance) for non-structured (left) and structured (right).



Three samples were tested two times each for the forceps type. The difference between the two groups is statistically significant (p-value<0.005).

**SHARKSKIN™ ILM forceps are part of the Grieshaber family of instruments.*

Figure 8: Average Coefficient of Friction (CoF) values for the GRIESHABER REVOLUTION® (left) and SHARKSKIN™ ILM (right) forceps when tested on the AIR OPTIX® contact lens model.*



Three samples were tested two times each for the forceps types. The difference between the two groups is statistically significant (p-value<0.005).

Masked wet lab study was performed by 13 surgeons who were asked to attempt grasping of the rabbit lens capsule using the same control and test forceps. Surgeons were then asked to fill out a questionnaire evaluating the relative ease by which they could grasp the lens capsule with the two forceps types. These results showed a statistically significant lower grasping force for the SHARKSKIN™ ILM forceps, as assessed by surgeons in this qualitative study (p<.0001) (Figure 10).9.

Figure 9: Average Coefficient of Friction (CoF) values for the GRIESHABER REVOLUTION® (left) and SHARKSKIN™ ILM (right) forceps when tested on the rabbit cornea model.

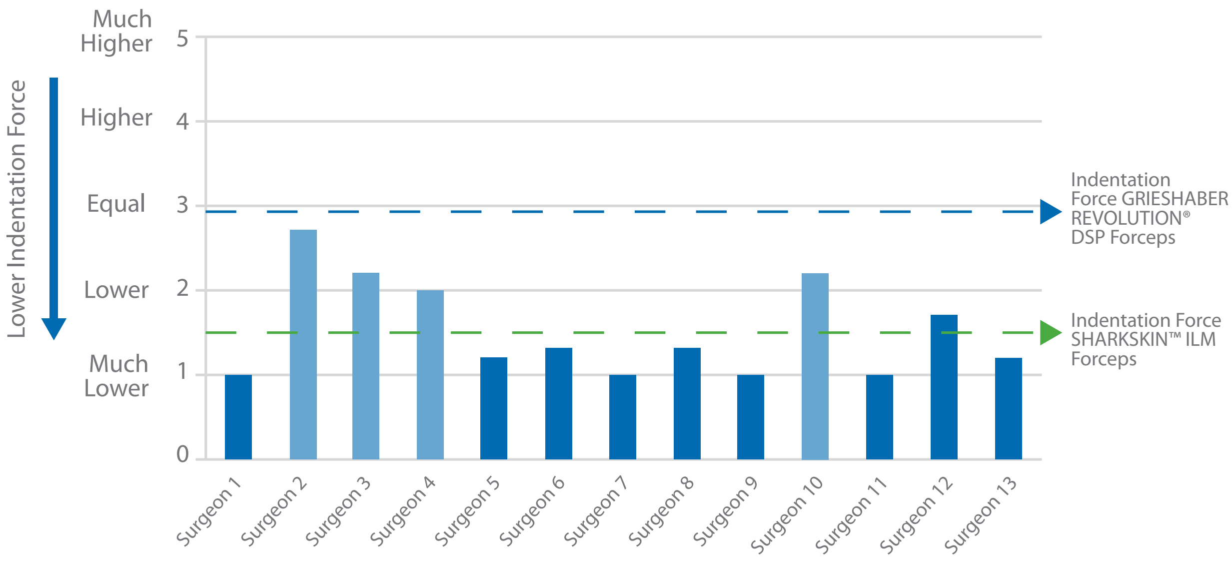


Figure 10: Surgeons assessed the force necessary to grasp the rabbit lens capsule using two difference forceps in a masked wet lab study.

To address varying preferences, SHARKSKIN™ ILM forceps come in 23, 25+® and 27+® gauges. Additionally, 27+® SHARKSKIN™ ILM forceps have been developed with an enlarged grasping platform, with the area almost equal to that of the 25+ gauge forceps (Figures 11 and 12). It is 59% larger than the prior 27-gauge platform and, thus, proportionately reduces pressure on the membrane, minimizing likelihood of it being shredded by excessive pressure, which is a complaint mentioned by some surgeons with the current 27-gauge forceps. Additionally, the new 27+® SHARKSKIN™ ILM forceps brings the same grasping platform shape as the 23 and 25+® gauge versions compared to the current 27+® gauge, which has a more rectangular shape. This may reduce the risk of pinching into the sensory retina with the edge of the grasping platform when grasping in an angled configuration.

Figure 11: 23/25+ Ga SHARKSKIN™ ILM Forceps

Figure 12: 27+ Ga SHARKSKIN™ ILM Forceps

Conclusions

The SHARKSKIN™ ILM forceps have been engineered in order to optimize the force necessary to grasp the ILM. Compared to other forceps, the SHARKSKIN™ ILM forceps require less force to grasp and have a higher coefficient of friction when tested on difference surfaces, such as the rabbit cornea and AIR OPTIX® contact lenses.

Preventing complications from excessive forces exerted on the retina during ILM peeling and/or from repeated grasping,[4] may be accomplished by the innovative design of the SHARKSKIN™ ILM forceps. Furthermore, SHARKSKIN™ ILM forceps also provide surgeons an innovative instrument, especially when grasping to create an edge for the initial flap, and the need for minimizing the amount of pressure applied to the retina during the maneuver to peel the internal limiting membrane.

Dr. Steve Charles: Surgeons' Challenges

Surgical Technique Suggestions by Steve Charles, MD

- Visualization is crucial for ILM peeling; I found that NGENUITY® 3D visualization system provided improved visualization by increasing depth of field allowing increased magnification
- A plano or aspheric contact lens improves visualization compared to non-contact visualization (BIOM*, ReSight*) because it eliminates all corneal asphericity and increases lateral and axial resolution
- The surgeon must approach ILM very slowly, scaled up position means velocity must be scaled down
- Initial grasp should be at the epicenter of striae (radial slight folds), the place where the membrane is most obvious, not at some standard location and definitely not temporal to the macula.
    - If nerve fiber layer is grasped, release and start again, do not keep pulling.
    - Peeling motion is similar to rhexis; circular and tangential to the retinal surface
- Finesse® Flex Loop is an appropriate tool to make an edge. Piks or MVR blades are too sharp, in my experience.
- ILM staining is helpful
    - I only use Brilliant blue. In my opinion it is the only optimal stain and it can and should be reapplied.
    - ICG has toxicity and should not be reapplied.
    - Trypan blue stains epiretinal membrane not ILM.
    - Triamcinolone is a particulate marking agent not a stain and not specific for any tissue -- definitely not ILM.
    - Surgeons should check regulatory approval status and availability of various stains in their locale.
- The larger the macular hole, the greater the wrinkling in an epimacular membrane case or the more extensive the schisis; the wider the diameter of ILM that must be peeled because the ILM is elastic, think Y term in Hooke's Law (F=-kY).

References

1. Abdelkader, Ehab, and Noemi Lois. “Internal Limiting Membrane Peeling in Vitreo-Retinal Surgery.” Survey of Ophthalmology, vol. 53, no. 4, 2008, pp. 368–396., doi:10.1016/j.survophthal.2008.04.006.

2. Semeraro, Francesco, et al. “Current Trends about Inner Limiting Membrane Peeling in Surgery for Epiretinal Membranes.” Journal of Ophthalmology, vol. 2015, 2015, pp. 1–13., doi:10.1155/2015/671905.

3. Gelman, Rachel, et al. “Retinal Damage Induced by Internal Limiting Membrane Removal.” Journal of Ophthalmology, vol. 2015, 2015, pp. 1–10., doi:10.1155/2015/939748.

4. David Steel et.al. “INTERNAL LIMITING MEMBRANE PEELING IN MACULAR HOLE SURGERY; WHY, WHEN, AND HOW?”, RETINA 0:1–13, 2017

5. Market Scope®, LLC. 2017 Retinal Surgical Device Report: A Global Market Analysis for 2016 to 2022

6. Alcon internal data on file. Grieshaber Market Evaluation Prepared by Andrew Stokes, Morten Andersen and Silvia Bodini 5th October 2017

7. Alcon internal data on file. Alcon Grieshaber “Slipless Forces” project, document number TR-0322 “Design Selection Slipless Forceps (Funnel screening)”

8. Alcon internal data on file. Alcon Grieshaber “Slipless Forces” project, document number TR-0370 “Tribological investigations of ophthalmic ILM forceps tips”

9. Alcon internal data on file. Alcon Grieshaber “Slipless Forces” project, document number TR-0330 “Wetlab Test”

GRIESHABER® DSP Important Product Information

CAUTION: Federal (USA) law restricts this device to sale by, or on the order of, a physician.

INDICATIONS FOR USE: GRIESHABER® DSP instruments are a line of single-use vitreoretinal microinstruments, which are used in ophthalmic surgery, for cases either in the anterior or the posterior segment. The GRIESHABER® Advanced Backflush Handles DSP are a family of instruments for fluid and gas handling in vitreoretinal surgery.

WARNINGS AND PRECAUTIONS:

- Potential risk from reuse or reprocessing GRIESHABER® DSP instruments include: foreign particle introduction to the eye; reduced cutting or grasping performance; path leaks or obstruction resulting in reduced fluidics performance.
- Verify correct tip attachment, function and tip actuation before placing it into the eye for surgery.
- For light fiber instruments: Minimize light intensity and duration of exposure to the retina to reduce risk of retinal photic injury. The light fiber instruments are designed for use with an ALCON® illumination source.
- Good clinical practice dictates the testing for adequate irrigation and aspiration flow prior to entering the eye. If stream of fluid is weak or absent, good fluidics response will be jeopardized.
- Use appropriate pressure supply to ensure a stable IOP.
- If unwanted tissue gets engaged to the aspiration port, it should be released by interrupting aspiration before moving the instrument.

ATTENTION: Please refer to the product labeling for a complete listing of indications, warnings, and precautions.

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