Introduction

BY DAVID F. CHANG, MD

We cataract surgeons and our patients continue to benefit from ongoing improvements in phaco technology. Because cataract surgery is already such a fast and efficient operation, we are primarily interested in new technologies that can expand our margin of safety—particularly in eyes with dense nuclei and weak zonules. Historically, our three main safety-related concerns with phacoemulsification have been (1) thermal damage to the incision, (2) endothelial trauma associated with prolonged ultrasound time, and (3) capsular rupture due to postocclusion surge.

Incision burns are most likely to occur with higher power levels and prolonged ultrasound times needed for brunescent lenses. Increasing the stroke length of the vibrating phaco tip generates more frictional heat as well as more phaco power. The thicker nuclear emulsate can admix with a highly retentive ophthalmic viscosurgical device (OVD) to form a viscous plug that clogs the phaco tip or aspiration line. If fluid outflow is blocked, then the gravity-fed inflow of irrigation also ceases. With neither inflow nor outflow of fluid to cool it, a phaco tip in continuous mode will instantaneously burn the cataract incision.

The loss of endothelial cells is also much greater with brunescent nuclei, the size and density of which require increased phaco time and energy for emulsification compared with standard cataracts. In my opinion, it is the increased particulate turbulence occurring with brunescent nuclear fragments that causes the most damage to endothelial cells. Rigid nuclear pieces drawn by aspiration to the phaco tip do not mold and conform well to its opening. This and the added stroke length of higher ultrasound power settings increase the chatter and turbulence of nuclear particles within the anterior chamber.

Finally, there are several reasons why posterior capsular rupture is more common with rock-hard nuclei. The added rigidity and girth of the nucleus more directly transfers instrument-related forces to the capsule and zonules, and there is far less of an epinuclear shell to cushion the movements of the endonucleus. We typically maximize vacuum levels to improve holding power in these cases, but this increases the risk of postocclusion surge. A lax posterior capsule due to weak or deficient zonules will trampoline more easily toward the phaco tip, making even a minor or momentary degree of surge precarious.

Fortunately, major manufacturers provide us with bona fide advances in their latest machine platforms that address the three problems I have outlined. My contribution below highlights specific safety features that users of the WhiteStar Signature System (Abbott Medical Optics, Inc., Santa Ana, California) should understand and deploy to obtain the best possible outcomes during cataract surgery.

Contributions from my colleagues Cristian Mircea Moraru, MD; Maria Cruz Ciprés, MD; and Rupert Menapace, MD; outline advances from Alcon Laboratories, Inc. (Fort Worth, Texas), Bausch & Lomb (Rochester, New York), and Oertli (Berneck, Switzerland), respectively. Each contribution summarizes how surgeons using that specific system can learn to perform phacoemulsification and cataract surgery most effectively, producing superior outcomes.

Strategies With the WhiteStar Signature

BY DAVID F. CHANG, MD

This decade has brought two major advances in ultrasound technology, starting with the launch of the WhiteStar software (Abbott Medical Optics, Inc.) in 2001. Shortening the pulse’s duration allows us to significantly increase the
frequency of ultrasound pulses. Additionally, the ability to decrease the duty cycle produces a major reduction in cumulative ultrasound time. These changes significantly reduce the production of heat and the total ultrasound energy delivered by the phaco tip, and they practically eliminate the risk of wound burn. As well illustrated by the American Society of Cataract and Refractive Surgery award-winning videos of Teruyuki Miyoshi, MD, with ultra-high-speed digital photography, alternating each ultrasonic pulse with rest periods of off-time diminishes the repelling force of the vibrating phaco tip. This in turn reduces the chatter and turbulence of small lenticular particles at the phaco tip that would otherwise bombard the corneal endothelium.

The second major advance was the OZil Torsional handpiece (Alcon Laboratories, Inc.), which replaces the axial movement of a traditional phaco needle with the sideways oscillation of a bent Kelman tip. Dr. Miyoshi’s videos also showed that eliminating longitudinal repelling forces at the phaco tip dramatically improved followability and reduced the chatter of fragments. Abbott Medical Optics, Inc., has built on this concept by blending some longitudinal movement with a transverse elliptical path of the phaco tip (Figure 1). Ellips Transversal Ultrasound retains some longitudinal motion to improve the tip’s ability to cut dense nuclear material. Although I have only limited personal experience with torsional phacoemulsification, Ellips seems to provide comparable benefits with a straight phaco tip, which is my strong preference for phaco chop (Figure 2). This is the single most exciting feature of the WhiteStar Signature System.

I now routinely combine Ellips with variable Whitestar ICE Technology, but I use a higher, footpedal-controlled duty cycle that I can vary from 60% to 90%. The higher duty cycle compensates for the overall reduction in the tip’s axial motion. The enhanced followability that characterizes Ellips Transversal Ultrasound is most dramatic and obvious when used on dense nuclei. The reduced endothelial trauma in eyes with brunescent lenses is apparent in the form of clearer corneas on postoperative day 1, a well-acknowledged hallmark of phacoemulsification using non-longitudinal ultrasound.

**MICROPHACO TIP**

Moving from a 19- to a 20-gauge phaco tip (Figure 2) is one strategy that all of us can use to enhance safety, regardless of the brand of phaco machine. This single modification reduces the size of the incision, decreases surge, lessens the chance of accidental aspiration of the iris or capsule, and makes it easier to pluck thin or crumbling nuclear fragments from the capsular fornices. The last advantage stems from the fact that the smaller tip becomes occluded without having to penetrate too deeply into the nucleus. The narrower lumen restricts flow, reduces surge, and prevents material from rushing in as fast as through a needle with a shaft of standard diameter. Like an I/A tip with a smaller opening, a microphaco tip provides us with greater control over which tissue is or is not aspirated. Slowing things down in this way helps when we want to guard against snagging the capsule, such as when aspirating epinucleus or thin nuclear pieces abutting the peripheral capsular bag.

Counterbalancing these advantages are several tradeoffs. A microphaco tip increases nuclear chatter because of its smaller mouth, and its restricted flow lengthens the time needed to remove a bulky nucleus. The smaller surface area of the tip’s opening also reduces the effective holding power for any given vacuum level. Fortunately, we can solve the followability problem by chopping the nucleus into smaller pieces and combining Ellips and variable WhiteStar power modulations to virtually eliminate chatter. Improved pump technology enables us to safely use higher aspiration flow and vacuum to compensate for the other factors. It is therefore possible to reap the benefits of a smaller phaco tip regardless of whether we perform coaxial or biaxial phacoemulsification. Yet using a microphaco tip is the most overlooked safety modification that we surgeons can make.

**ENHANCED FLUIDICS**

The WhiteStar Signature System’s pump is a measurable improvement over that of the Sovereign. Randall J. Olson, MD, of Salt Lake City, Utah, measured surge associated with a variety of vacuum levels using different machines with the same experimental cadaveric eye. These studies have provid-
ed quantitative confirmation of the improved chamber stability that we perceive clinically. I also strongly advocate using two optional but important safety features of the Signature's Fusion Fluidics pump: passive automatic reflux and the antisurge algorithm (discussed later).

We are more likely to aspirate a lax posterior capsule during cortical clean-up in eyes with weak zonules. All phaco machines provide active auto reflux, whereby pressing a footswitch reverses flow in the aspiration line.

Doing so expels ensnared material, such as the posterior capsule, from the aspirating port. Passive auto reflux is a safety option of both the Signature and the Sovereign that automatically refluxes the port at every transition from foot position 2 to 1. We surgeons instinctively make this change as soon as the capsule is aspirated, and this wonderful safety feature immediately expels the capsule for us. I select this indispensable option for all cases.

**ANTISURGE ALGORITHM**

I believe that postocclusion surge is still the most common cause of posterior capsular rupture occurring during nuclear emulsification. The Diplomax machine (Abbott Medical Optics, Inc.) was the first to offer the occlusion mode feature, which we could program to automatically change ultrasound and fluidic parameters once the phaco tip became occluded or unoccluded. I always thought, however, that it would be much safer if we could drop the vacuum immediately before a break in occlusion. When using higher vacuum levels, this decrease would significantly reduce surge and improve chamber stability.

In response to this suggestion, the Fusion Fluidics pump technology has an antisurge algorithm to accomplish just this result. The pump’s onboard computer recognizes occlusion and proactively reverses the pump to actively step down the vacuum before the break in occlusion occurs. I use the antisurge algorithm during emulsification of chopped fragments, when breaks in occlusion are happening repeatedly. Like a car’s antilock braking system, the antisurge algorithm automatically reduces the vacuum level after a predetermined interval to prevent surge as the fragments are evacuated. The algorithm tries to automate and duplicate what an experienced surgeon could do with a dual linear foot pedal once the tip becomes occluded. High vacuum is first used to maximize holding power, but we would then lower the vacuum with the dual linear foot pedal before delivering phaco power to clear the phaco tip.

**CONCLUSION**

Advances in phaco technology continue to improve our ability to manage the most challenging cataracts. Although such sophistication comes at the expense of simplicity, understanding and properly configuring our phaco technology allows us to deliver better performance while improving safety.

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Strategies With the Infiniti and OZil

**BY CRISTIAN MIRCEA MORARU, MD**

Many innovations and improvements in phacoemulsification have occurred in the past 20 years, allowing options tailored to different degrees of nucleus density. Although ultrasound previously was used only in continuous mode, ultrasonic energy can now be fixed-continuous; linear-continuous; or modulated in pulse shape, burst-microburst, micropulse, or hyperpulse.

OZil torsional technology has once again revolutionized the way ultrasonic energy is released. The transition from longitudinal movement (40 kHz) to side-to-side movement (32 kHz) of the Kelman phaco tip has made ultrasound more efficient and productive with lower parameters. The Kelman Mini-Flared 45° phaco tip (Alcon Laboratories, Inc.; Figure 3) significantly reduces the rate of clogging in very hard cataracts.

Since torsional ultrasound was introduced, Alcon has improved the performance of the Infiniti with new software; the Kelman Mini-Flared tip (and the Ultrasleeve); and the Intrepid FMS, which nearly eliminates postocclusion surge. I use the Infiniti with OZil in all kinds of cataracts, including grade 4+ and above. My technique is coaxial microincision cataract surgery (MICS) with a 2.2-mm incision.

Given multiple possibilities to set its parameters, I have created a simple package of settings that produces excellent outcomes during surgery as well as on the first postoperative day, ensuring better outcomes and a clear cornea. Parameters include: (1) issuing ultrasound as continuous, pulse, or burst in either fixed or linear mode, (2) fixing minimum and maximum values for ultrasound, (3) varying the time between the active and inactive ultrasound periods with the time-on/time-off parameter, and
using vacuum and aspiration rate in fixed or linear mode, dynamic rise, and custom pulse mode. I typically use quick chop phaco (see Parameters for Quick Chop Phaco), and the Infiniti Vision System with OZil allows me to successfully extract any type of cataract.

I typically use pulsed ultrasound in linear mode (40–80%) during quick chop phaco. With this setting, chopping breaks up any cataract because we can modulate and control the linear ultrasound power with the footpedal. If you use continuous ultrasound, set the minimum and maximum values based on the hardness of the nucleus to prevent the phaco tip from clogging in a hard cataract. For very soft cataracts, we use only vacuum power to penetrate and fixate the nucleus. The following settings allow more efficient vacuum: 10% irrigation (position 1), 70% I/A and vacuum (position 2), and 15% ultrasound (position 3).

During quadrant removal, I always use continuous torsional ultrasound in linear mode. A minimum 40% starting value should be used to avoid clogging at the phaco tip. Maximum power must correlate with the degree of nucleus hardness, even on grade 4+ to 5+ cataracts. For grade 1+ and 2+ cataracts, I use a minimum amplitude of 30% to 40% and a maximum amplitude of 50%. For 2+ or 3+ cataracts, I increase the minimum amplitude between 40% to 50% and the maximum amplitude between 60% and 70%. Lastly, for grade 4+ or 5+ cataracts, I use a minimum amplitude of 60% to 70% and a maximum amplitude of 80%. To prevent endothelial cell damage, the maximum ultrasonic amplitude should not be higher than 80%. Additionally, the phaco tip must be held in vertical position (with the tip down) for maximum efficiency of torsional ultrasound.

Because the nucleus is fragmented into small portions, phacoemulsification is fast and smooth, with high followability and no repulsion or chatter. The nuclear pieces come to the phaco tip, located in the center of the anterior chamber—the nuclear matter appears to melt away.

We use the following parameters: dynamic rise, 0; vacuum, 300 mm Hg in fixed mode; aspiration rate, 25 cc/minute in fixed mode. Turbulence, the second most important factor for endothelial damage after ultrasound, is minimal. The fixed vacuum and aspiration rates increase phacoemulsification speed without being dangerous at these low values.

For the epinucleus, we use I/A with the irrigation bottle at 95 cm, vacuum at 450 mm Hg in linear mode, and aspiration rate at 45 cc/minute in fixed mode. The dynamic rise is set to -2. The same parameters are used for bimanual I/A for cortex aspiration. We may add torsional ultrasound (maximum amplitude, 20%) in linear mode in the case of a consistent epinucleus. Increasing the vacuum to 300 mm Hg linear and lowering the aspiration rate to 30 cc/minute fixed will speed epinucleus aspiration.

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**Strategies With the Stellaris**

**BY MARIA CRUZ CIPRÉS, MD**

Surgical techniques for cataract removal have advanced rapidly, especially in the past decade. In my opinion, one of the greatest developments for cataract surgery has been the introduction of biaxial MICS. The benefits of biaxial MICS include less induced astigmatism, faster healing, and better visual recovery compared with other phaco techniques.

This technique uses pulsed phaco power to avoid generation of high temperatures and, thus, to prevent surgical trauma such as corneal wound burns. Combining biaxial MICS with the Stellaris Vision Enhancement System, I have...
achieved outstanding results and seen a higher level of patient satisfaction.

The Stellaris' new EQ Fluidics system, as well as its six-crystal handpiece and accurate power modulation software reduce surgical risks. Biaxial MICS with the Stellaris is a safe and effective technique for cataract surgery because it allows me to reduce induced astigmatism and provide patients with faster visual recovery. The phaco handpiece on the Stellaris provides low-frequency ultrasound (28.5 kHz), thus allowing efficient cutting and optimized cavitation. Additionally, it creates a lower mean power as compared with its predecessor, the Millennium (Bausch & Lomb).

Other than reducing my incision size to 1.4 mm with biaxial MICS, I use the same cataract removal technique (ie, phaco chop) as I do for standard coaxial or coaxial MICS. The first incision I make is a trapezoidal clear corneal incision in the temporal cornea, followed by a second located 160º to 180º from the first. I have found that this technique avoids wrinkling in the cornea. I always remove the OVD prior to hydrodissection and hydrodelineation to prevent the nucleus from falling into the vitreous humor. I turn the tip of the irrigating chopper horizontally, inserting it with a clockwise motion, and begin continuous anterior chamber infusion. The phaco needle is inserted bevel down to avoid damage to Descemet’s membrane. It is only safe to rotate the needle once it is inside the eye.

Recently, I conducted a prospective, comparative study of 100 consecutive biaxial MICS cases with the Stellaris and 100 biaxial cases with the Millenium (Bausch & Lomb). Fifty-one percent of patients had a grade 4+ cataract, and 43% had a 3+ grade cataract. I used the following parameters with the Stellaris: bottle height, 110 cm; vacuum, 150 to 550 mm Hg; ultrasound mode, fixed burst; ultrasound power, 0% to 10%; pulse length, 6 milliseconds; interval, 8 milliseconds; duty cycle, 0; and footpedal, dual linear. I performed phacoemulsification with a 20-gauge needle through a 1.4-mm incision, which was enlarged to 1.7 mm during insertion of the Akreos MI60 (Bausch & Lomb).

Using the EQ fluidics system and the vacuum pump with StableChamber tubing (Figure 4) allowed more precise control of the balance of aspiration and irrigation. These tools help to prevent postocclusion surge, allowing less decompression, better followability, and reduced hydrodynamic trauma.

Additionally, the six-crystal handpiece and accurate power modulation of the Stellaris delivered significantly less energy.

In all cataract cases, the mean power was less than 9%. In the grade 4+ Stellaris group, I used mean power of 6.92%, and my absolute phaco time was 0.0317 seconds. In the grade 3+ Stellaris group, mean phaco power was 4.74%, and absolute phaco time was 0.0190 seconds. I used 71.53 J of energy in the grade 3+ Stellaris group (13.74% less energy delivered than the Millenium) and 123.89 J in the grade 4+ Stellaris group (42.31% less energy delivered than the Millenium).

Biaxial MICS has recently gained popularity. Because it is a safe and effective as conventional cataract surgery, biaxial MICS with the Stellaris is the next step in the continued process of advancing my cataract surgery technique and minimizing the incision size.

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with other MICS lenses, which require incision enlargement to between 1.8 and 2 mm. These include the Akreos MI 60 (Bausch & Lomb: 1.8-mm wound-assisted), the Micro AY (PhysIOL, Liege, Belgium: 1.8 mm wound-assisted), and the iMics (Hoya Healthcare Corp., Tokyo: 2 mm, inserted). For standard mini-incision phaco, I use the new easyTip (Oertli; Figure 5) with a 2.2- to 2.4-mm clear corneal incision (CCI). Although it has a similar design as the CO-MICS tip, it has a larger diameter and reduced bevel angle. I use it with standard one-piece IOLs, such as the AcrySof (Alcon Laboratories, Inc.) or Acri.Tec.

With regard to differences in induced astigmatism, we are currently collecting data to see if downsizing the CCI to 2.4, 2.2, and 1.8 mm will eliminate induced astigmatism. From previous work, we know that a 3-mm CCI induces clinically significant astigmatism because it causes asymmetric sectorial flattening central to the incision, which encroaches upon the pupillary center. We are now investigating to what extent the smaller CCIs also cause such flattening and whether this is clinically relevant to the 5-mm pupillary zone.

With the 45° bevel of the easyTip, and even more so with the 53° bevel of the CO-MICS 2 tip, a modified divide-and-conquer technique is most efficient and safe. For nuclear separation, a direct-crack technique—analogous to the direct-chop—is used. Rather than directing the bevel upward, the surgeon turns the bevel sideways. With the tip turned to the surgeon’s right (for right-handed surgeons), the cortex is first shaved off. Then, the direct-crack maneuver follows without pregrooving. With the bevel still turned to the right, the tip is introduced steeply into the center of the nucleus, and the nucleus is then cracked with a spatula. Due to the strong bevel, this can be achieved with one or two passes. The two halves are further divided into quadrants in a similar fashion. Care is taken to completely free the quadrants from any adherences before aspiration.

The quadrant aspiration technique is also modified. Normally, the surgeon would lift the central tip of the quadrant upward and engage it with the phaco needle. With the 45° and 53° tips, the bevel is tilted sideways and brought near to the flank of the freed quadrants to ease occlusion. This time, the bevel is turned to the left, thereby gaining easy access for the spatula to the tip opening. High flow and vacuum settings are used, thereby enhancing power coupling and reducing energy consumption while avoiding chatter. The slim shaft counteracts surge, avoiding trampolineing of the capsular diaphragm and making quadrant aspiration safe.

Both tips allow much higher fluidic settings compared with their parallel-walled counterparts. The slim shaft has a small bore that increases flow resistance while the increased cross-section of the sleeve augments fluid inflow. Both effectively counteract surge and allow higher flow and vacuum settings. Flow rates up to 50 mm/min and vacuum presets of up to 600 mm Hg may be used with the 2.2-mm easyTip; however, lower settings must inherently be used with the smaller CO-MICS 2 tip. To enhance infusion supply with the latter, an infusion spatula may be used (Figure 6). I have termed this technique infusion-assisted or hybrid phaco, as it is derived from the biaxial approach. The additional inflow allows the use of higher fluidics and ensures a rock-solid chamber. The ability to mechanically protect the posterior capsule from contacting the blade-like bevel of the CO-MICS 2 tip provides the surgeon with additional safety. Followability, occludability, and holdability are enhanced, with these high settings, as well as the efficiency of microphacoemulsification. Bouncing or chattering of nuclear fragments is eliminated, as is trampolineing of the posterior capsule. In fact, our own comparison study has demonstrated that phaco energy consumption is reduced by more than 50% when using infusion assistance, and fluid consumption increases by 25%.

There is no question that phaco efficacy is enhanced by increasing fluidics parameters. An alternative approach is implementing additional oscillating movements to the phaco tip. Although this technology is being promoted, data from well-conducted studies are missing. With tips that allow high fluidics and optimize energy transfer, emulsification has become so efficient that the amount of phaco energy required may be tremendously decreased. With this in mind, the power modulation and additional nonaxial tip oscillation technologies have lost much of their importance. Well-conducted studies are needed to detail the advantage of using such technologies as OZil or Ellips.
With the Oertli machine, the surgeon can switch between peristaltic and venturi pumps. I routinely use the peristaltic pump. It provides me with perfect control of flow and vacuum during capsular polishing, when I abrade the lens epithelial layer from the anterior capsule with a sharp-edged device, or with lens fiber peeling, when I intentionally aspirate the posterior capsule to gain occlusion for peeling off residual lens fibers from the posterior capsule.

Also with the venturi pump, I appreciate the efficiency, especially when the rise time is set at 100%. Using the peristaltic pump setting, the surgeon can reach for a chunk, occlude, and wait for vacuum build up, the speed of which can be modulated via the flow rate. With the venturi pump, the chunk is attracted, and vacuum build-up can be set to immediate. It is important to note that with the new slim-shaft Oertli tips, a high vacuum preset is required to overcome the fluid resistance of the small bore. Otherwise, the peristaltic pump will stop prematurely before the preset flow rate is attained. As a rule, the vacuum limit is set at least 150 mm Hg higher with the new slim-shaft tips than with a parallel-walled standard tip. This, and the increased internal flow resistance, make the peristaltic pump perform similar to a venturi pump. Thus, this combination provides efficiency similar to the venturi pump with the control and safety of the peristaltic pump.

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