Using ultrasound energy to break and remove lens material was proposed by Charles D. Kelman, MD, and Anton Banko in 1967. Since their pioneering attempts, cataract surgery has evolved to routinely incorporate phaco machines and techniques. However, the mechanisms underlying the emulsification of cataracts are still debated. This article provides an overview of how phacoemulsification works and discusses some recently introduced ultrasound technologies that have enhanced the efficiency of the procedure and improved postoperative results.

**TIP MOVEMENT**

The core of the phaco handpiece (Figure 1) is a transducer that converts electric energy into mechanical movement of the phaco tip. This is possible due to the piezoelectric effect, whereby some crystals exhibit properties that produce electricity in response to applied mechanical stress. The piezoelectric effect is a reversible process, in that materials exhibiting the direct piezoelectric effect also exhibit the reverse piezoelectric effect—the internal generation of a mechanical force (deformation) resulting from an applied electrical field. Applying a high-frequency current induces these crystals to oscillate at a particular frequency. The oscillation is transmitted to the phaco tip via an ultrasonic horn, which also acts as an amplifier, and thus longitudinal backward and forward movement of the phaco needle (stroke) is achieved. This is the traditional longitudinal form of phacoemulsification. Some of the energy applied is dissipated into heat. The frequency at which a material naturally vibrates is called its resonant frequency, or the optimal frequency required to obtain the maximum mechanical amplitude and to reduce heat production.

The characteristics of stroke are length and frequency. Longitudinal phaco needle movement can reach a maximum of 100 to 120 µm, and the working frequency ranges from 28 to 45 kHz. The stroke frequency is defined by the manufacturer and cannot be modulated by the surgeon. Stroke length can vary linearly with application of the footpedal. Some argue that longer stroke length may generate more heat and corneal damage.

**HOW IT WORKS**

The aim of phaco technology in cataract surgery is to break the lens material into pieces and then emulsify and aspirate it through the phaco tip. In traditional longitudinal phacoemulsification, the phaco needle moves back and forth, mechanically cutting the lens material during the forward movement. This is known as the jackhammer effect. Microcavitation bubbles form during the high-speed back and forth movement. The role of cavitation is debated among the ophthalmic community. Some suggest that cavitation plays an active role in lens fragmentation, but others believe it has no useful function.

During forward movement of the phaco tip, the lens material is repulsed, the vacuum at the tip circumference decreases, and the bulk of the lens material may chatter. This can be compensated for by increasing the flow rate and the tip movement in the anterior chamber to regain occlusion.

The term followability is used to describe a relatively feathery and continuous aspiration of lens fragments into the phaco tip. A high level of followability implies less movement in the anterior chamber, less stress on the internal structures of the eye, and an overall increase in phaco efficiency. Longer strokes may provide a higher degree of lens-disrupting capability due to the greater jackhammer effect on the material. On the other hand, a longer longitudinal stroke may cause a higher degree of repulsion and chattering of the lens material, which may lead to longer surgical times. Smaller but more frequent strokes may provide better followability, resulting in good lens fragmentation.

Corneal endothelial damage and wound tunnel burns are two potential side effects of phaco energy that must be minimized. These events are related to the amount of energy delivered and the amount of heat produced. In
recent years, phaco power modulation controls such as micropulse energy delivery systems have been developed to reduce repulsion and increase followability, limiting the total amount of the energy delivered to the eye. More recently, other removal modalities have been introduced.

NEW-GENERATION PHACO MACHINES

In 2005, Alcon Laboratories, Inc. (Fort Worth, Texas), introduced the Infiniti OZil torsional phaco tip. This phaco tip exhibits an oscillatory movement along the longitudinal axis. If a bent tip is mounted, the torsional oscillation produces a side-to-side movement of the end of the tip. The cataract is cut by shearing the material rather than by the jackhammer effect. The repulsion of the lens bulk is minimized, improving followability. Interestingly, the rubbing effect of the tip against the corneal tunnel is reduced because the tip rotational movement is limited to approximately 40 µm, and the length of the side-to-side movement at the end of the tip is up to 100 µm.18

In 2007, Abbott Medical Optics Inc. (Santa Ana, California) released the Ellips Transversal Ultrasound handpiece for the company’s Whitestar Signature phacoemulsification system. The Ellips technology is based on an elliptical path of tip movement, combining side-to-side and longitudinal strokes. The stroke of the FX version, introduced in 2010, follows an elliptical pattern in a complex 3-D fashion.19

The transversal stroke of the Ellips can be achieved with straight or bent phaco tips. The torsional stroke of Alcon’s Infiniti OZil requires a bent tip to obtain the side-to-side movement. Torsional and transversal phacoemulsification systems improve phaco efficiency by reducing the chattering effect, the total phaco energy delivered, and overall surgical time. Corneal endothelial damage and wound tunnel burns are also minimized.18-21

CONCLUSION

Phacoemulsification has significantly evolved in the more than 40 years since its first description, becoming a faster and safer procedure. Recent-generation phaco machines

offer novel removal modalities with extraordinary fluids and phaco control. Surgeons have a wide range of settings to choose from according to their preferences and to the nature of the cataract they are extracting, leading to an almost customized phaco procedure for every patient. ■

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