Despite recent advances in techniques and technology, phacoemulsification in a rock-hard nucleus is challenging, even for an experienced surgeon. Hard cataracts are common not only in the developing world, but in the developed world as well. In these situations, the incidences of capsular-zonular complications, corneal edema, wound burn, and postoperative inflammation are high; however, the operating surgeon can achieve gratifying results if a proper and effective surgical strategy is adopted. This article presents my approach to ensure a successful outcome in eyes with rock-hard nuclei.

PREOPERATIVE EVALUATION
A meticulous preoperative evaluation is required prior to scheduling phacoemulsification. Because there is potential for collateral intraocular damage with hard nuclei, I evaluate the ocular tissues including the cornea under the zone of specular reflection. I also perform specular microscopy and pachymetry to objectively evaluate the corneal status. In rare cases, I consider manual small-incision cataract surgery (SICS) over phacoemulsification in the presence of an unhealthy cornea. Extracapsular cataract extraction is another alternative in these situations.

Other parameters that I routinely evaluate during the preoperative examination include anterior chamber depth, maximum mydriasis, and presence of iridophacodonesis. I always grade the hardness of the nucleus as cataracta nigra, cataracta rubra, or brunescent cataract based on its appearance at the slit lamp for two reasons: (1) the Lens Opacities Classification System III (LOCS III), useful as it is, does not always reflect the relative nuclear sclerosis of the hardest grades of cataract (Figure 1) and (2) assessment under the operating microscope may be misleading, as a bright fundus reflex does not always mean a softer cataract (Figure 2). Some of the fiercest cataracts I have seen were associated with a misleading red fundal glow under the surgical microscope.

When the degree of cataract precludes a good view of the fundus, I take a B-scan ultrasonograph of the posterior segment to detect vitreous opacities or retinal detachment. Because optical biometry may not be the best strategy to calculate IOL power in these super-hard cataracts, I often resort to immersion A-scan biometry.

INTRAOPERATIVE CARE
Anesthesia. Topical anesthesia with monitored anesthetic care using xylocaine jelly 2% is preferred unless
there is an associated comorbidity or I expect a long operating time with excessive intraoperative manipulations, such as in eyes with a small pupil, poor visibility, weak zonules, pseudoexfoliation, or subluxation. In these cases, local anesthesia is preferable. This method may also be more desirable for a less experienced surgeon, who may require additional surgical time or encounter intraoperative complications including posterior capsular tears and zonular dialysis.

Incision. Unless there is a strong possibility of aborting phacoemulsification, I create a temporal clear corneal incision. The alternative is performing surgery through a scleral tunnel, making it easier to convert to a safer manual SICS technique if needed.

Capsulorrhexis. An intact, relatively large capsulorrhexis is paramount for hard nuclei. Many elderly patients have a lusterless cornea or a thick arcus senilis that impairs visibility. In the absence of a good red fundal glow, staining the anterior capsule under an air bubble with trypan blue 0.06% can facilitate the capsulorrhexis. A visible rhexis margin (Figure 3) can prevent inadvertent damage during nuclear emulsification, such as phacoemulsification of the anterior capsule edge or passage of the chopper on top of the anterior capsule.

If intralenticular pressure is high, I perform a two-stage procedure, starting with a small capsulorrhexis of 3.0 to 3.5 mm in diameter to reduce the risk of rhexis run-off to the periphery. I then enlarge it to the desired size after aspirating flocculent cortex to decompress the capsular bag.

Hydrodissection. Cortical-cleaving hydrodissection should be performed gently to minimize rapid pressure build-up and prevent posterior capsular rupture; a larger capsulorrhexis is an advantage in this respect. It is important to remember that the posterior capsule tends be thinner in rock-hard cataracts, especially in women. I gently tap the nucleus down after each effort with cortical-cleaving hydrodissection to terminate capsulolenticular block and decompress the posterior chamber.

PEARLS FOR NUCLEUS MANAGEMENT

Protecting the endothelium. Surgery in a hard cataract is usually prolonged and requires more manipulations and ultrasound power than in softer nuclei. Therefore, in addition to proper surgical technique, measures that further protect the corneal endothelium must be considered. Endothelial protection is best achieved under a dispersive, retentive ophthalmic viscosurgical device (OVD) because it is retained as a protective layer, unlike a cohesive OVD, which flushes from the chamber within seconds of initiating phacoemulsification. Arshinoff’s soft-shell phaco technique is a great help in this regard.

I perform phacoemulsification entirely within the capsular bag, at a safe distance from the corneal endothelium. In the presence of a very shallow anterior chamber, I create a crater in the anterior nucleus before initiating nuclear disassembly. Chatter, resulting from the use of high longitudinal phaco power or from irrigation flow currents, may be a significant cause of postoperative corneal edema. It can be controlled by decreasing phaco power, coupling the nuclear piece against the phaco nee-
dle with a second instrument, or adjusting the direction of flow of irrigating fluid from the phaco sleeve.

**Nucleus disassembly.** The nucleus can be removed in a variety of methods including phaco chop, stop-and-chop, and divide-and-conquer. Before attempting to directly chop a hard cataract, one should create more space in the anterior chamber by carefully debulking the central nucleus, thus allowing phaco maneuvers to be performed further from the endothelium and creating a weak zone that is easier to crack. This sculpting also allows impaling the nucleus at a deeper level with the phaco needle, which facilitates the chopping process.

I use a 30° standard phaco tip for all steps of nucleus disassembly because it sculpts well and is easy to occlude during chopping maneuvers. Debulking can take the form of a crater, a short but deep trench, or a combination of the two (Figure 4). Relatively high phaco power might be required for sculpting at this stage, to minimize inadvertent nuclear displacement and avoid zonular stress.

**Chopping.** I prefer vertical chopping to horizontal chopping because the former is more efficient and relatively faster in my hands. The distal tip length of most choppers is 1.25 to 1.50 mm, which should sufficiently reach the middle of a standard nucleus and create a reliable chop. A hard cataract, however, is often more than 4.00 mm thick, and, therefore, a chopper with a long, sharp distal end of approximately 1.75 mm is more suitable (Figure 5).

Using burst mode, the phaco tip should impale the nucleus at its deepest level, where sculpting was previously performed. High vacuum is necessary at this stage for a good hold on the nucleus. The chopper is then buried deep into the substance of the nucleus near the capsulorhexis margin and advanced toward the phaco tip. Any fluffy cortical material near the rhexis margin should be removed to allow proper depth perception of the chopper tip (Figure 6). Then the surgeon can proceed, cracking or splitting the nucleus with lateral separation (Figure 7).

If the posterior nuclear plate is leathery, the crack may not extend through. In this event, regrasp the nucleus at a deeper plane, just anterior to where the crack has extended, and repeat the same chopping maneuver until a full-thickness crack is achieved. For more tips on dealing with a leathery posterior nuclear plate, see below.

Efforts to perform extreme degrees of lateral separation must be controlled to minimize excessive stretching and distortion of the capsular bag and avoid capsular-zonular complications. A frequent error by the neophyte surgeon is to create lateral separation at a more superficial plane, as using an inadvertent burst of phaco at this stage can result in tearing of the rhexis margin.

The nucleus is then rotated, and the same process is repeated until the nucleus is chopped into bite-size pieces. Failure to engage the nucleus at a deeper plane may result in inadvertent tilting of the nucleus, which can transmit stretching forces to the zonules via the capsular bag. Early removal of the first piece of nucleus may help to create more space in the bag so that successive subchopping maneuvers are easier.

A horizontal subchopping technique can create smaller nuclear fragments, which are then consumed by the phaco tip under lower vacuum, flow, and power settings. Keeping the tip bevel sideways can provide extra endothelial protection and enhance visibility. It is important to confine these maneuvers entirely within the capsular bag and below the iris plane. Frequent OVD replenishment may be required for endothelial protection.

Finally, care should be exercised when removing the last piece of nucleus, as the posterior capsule is vulnerable...
at this stage, and violent surge can result in a posterior capsular tear by the phaco tip or the chopping device. Decreasing vacuum and breaking occlusion slowly are also advised because there is no epinuclear protection in these cases. Early in this stage, I exchange the sharp chopper for a blunt chopper or Sinskey hook to prevent this mishap. I also prefer frequent injections of a dispersive OVD into the capsular fornix. If there is any difficulty during chopping, I have the option to revert back to a traditional stop-and-chop or divide-and-conquer technique.

**Leathery posterior nuclear plate.** A frequent finding in brown cataracts is the presence of chopped fragments that remain adjoined in the center. These can resist being drawn into the mid-anterior chamber for complete phacoemulsification (Figure 8A). The posterior nuclear plate has a leathery quality in hard, brunescent cataracts. This plate develops from the epinucleus, which can become stiff and tether to the nucleus, making it difficult to crack. This challenge can be dealt with in the following ways: (1) use of a long chopper, (2) deep sculpting prior to initiating the chopping, (3) dissection or transection of the strands with a horizontal or blunt-tipped chopper. The nuclear fragment must be stabilized with adequate vacuum; then the phaco tip is raised a bit, and the interconnecting adhesions are lysed using the second instrument (Figure 8B). Alternatively, the surgeon can bimanually separate the interconnecting adhesions with two Sinskey hooks implanted through the paracenteses and placed adjacent to the interconnecting fibers. The Sinskey hooks are then moved apart in a cross- or direct-action maneuver (Figure 8C). Prior to this maneuver, the capsular bag should be inflated with an OVD and the nucleus partially floated into the bag by injecting a dispersive OVD behind it.

**Wound burns.** Because higher phaco power is used for hard cataracts, wound burn is a potential complication (Figure 9). Furthermore, in eyes with difficult access, the surgeon may involuntarily press the phaco sleeve against the wound, choking the flow around the phaco tip and

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**Figure 8.** (A) Incompletely separated fragments in a hard cataract with a leathery posterior nuclear plate. (B) Lysis of the interconnecting fibers is performed using a blunt chopper. (C) Interconnecting fibers are separated using two Sinskey hooks.

**Figure 9.** Wound burn, a potential complication of using higher phaco power to remove hard cataracts.

**Figure 10.** Residual nuclear fragments in the angle (arrows).
inviting wound burn. For this reason, some surgeons advocate frequently wetting the wound with irrigating solution while phaco energy is used. A clogged phaco needle or tube may also lead to heat-related trauma if it is not immediately recognized and the offending chunk flushed out of the system. Thermal burns may be avoided by using appropriate power modulation, especially hyper-pulse modes with variable duty cycles and burst modes. Torsional and transversal ultrasound are beneficial in this context because they help reduce chatter.

Wound burn is often preceded by the appearance of lens milk (lens smoke) and accompanied by whitening and contracture at the incision site. In this event, the original site should be abandoned and phaco continued from a fresh incision after taking care of the factors resulting in the wound burn.

Residual nuclear fragments. Chopping in hard cataracts can leave behind residual nuclear bits that show up postoperatively with attendant iritis or focal corneal edema (Figure 10). This is more often seen in patients with thick arcus senilis, when intense stromal hydration has been used, or when intraoperative miosis has occurred. The chips may hide in the anterior chamber angle, a subincisional site, or the posterior chamber. There should be a high index of suspicion for this phenomenon. Whenever I see a small nuclear bit, I immediately go for it because they tend to go out of view if removal is postponed.

CONCLUSION
Phacoemulsification is challenging in patients with rock-hard nuclei. Because it is associated with a higher incidence of significant complications, a thorough surgical technique that protects the corneal endothelium is mandatory. With a judicious mix of proper technique and appropriate technology including power modulation and enhanced fluidics, good results can be achieved in these cases.

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TAKE-HOME MESSAGE
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