Incisional Temperature: An In Vitro Study

The thermal factors of bimanual microincisional phacoemulsification.

BY ROBERT H. OSHER, MD

Although microincisional sleeveless phacoemulsification has attracted the attention of cataract surgeons, the widespread adoption of this emergent surgical method is contingent upon the successful demonstration of patient safety in regard to various complications, including thermal injury at the incision site. Thermal damage can occur with all phaco systems, despite claims of "cold" lens removal capabilities. In order to maximize the safety of bimanual microincisional phacoemulsification, the surgeon must understand the thermal effects of a different incision size and other surgeon-controlled parameters, such as aspiration flow rate, vacuum setting, ultrasound power, and duty cycle. I believe that these parameters are not yet well understood in relation to microincisional phacoemulsification and may therefore contribute to elevated incisional temperatures.

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STUDY DESIGN

In order to determine how various surgeon-controlled parameters affect heat generation at the microincision site, I designed an in vitro study using the Infiniti Vision System (Alcon Laboratories, Inc., Fort Worth, TX), which offers an extremely accurate, linear, low-end power curve and precise hyperpulse control. The study used banked cadaver eyes and pig eyes. Testing was performed at room temperature (including the globes), and the incision's temperature was monitored with a Thermacam P60 Infrared Camera (Flir Systems, Inc., Boston, MA) at various time intervals. I visually observed the clinical response at the incision site, and thermal injury was seen at temperatures between 40º and 45º C. The incision was made at the corneal-scleral junction with standard surgical knives. Extreme care was exercised to construct each incision in the same manner.

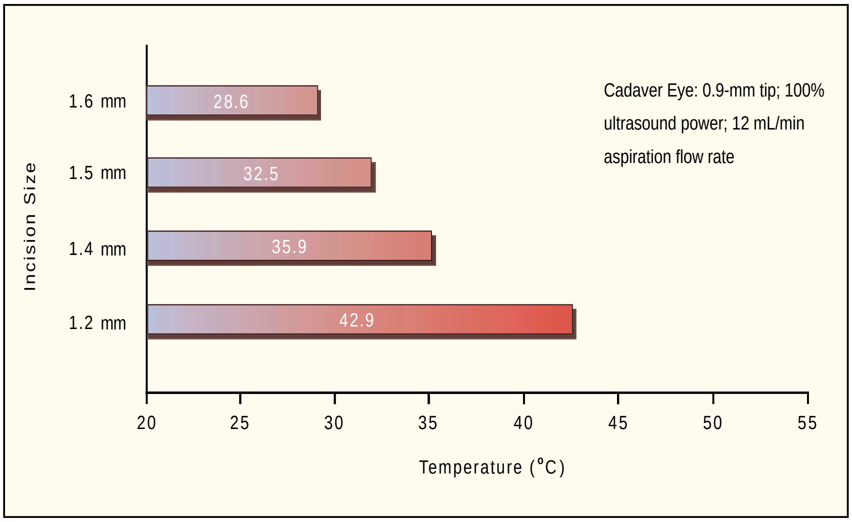

Figure 1. Higher temperatures were observed with tight incisions.

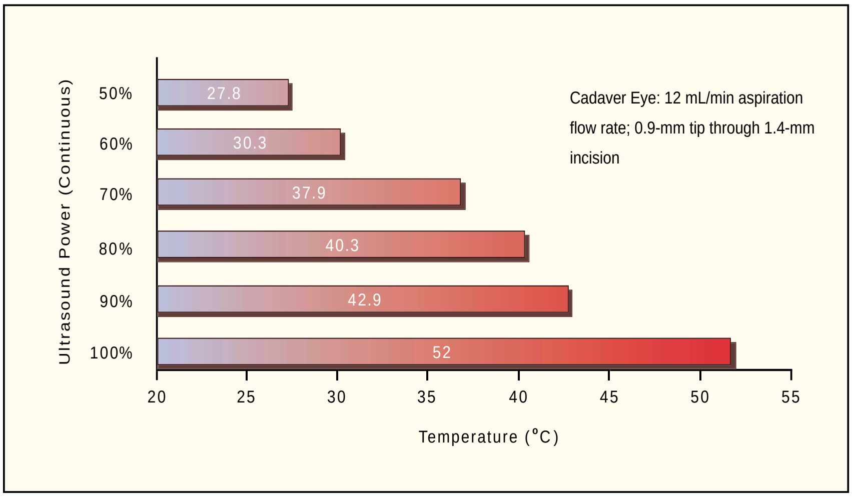

Figure 2. Lower ultrasound powers produced lower incisional temperatures at 10 seconds.

SURGEON-CONTROLLED PARAMETERS

Incision Size

I used a 0.9-mm sleeveless ultrasound tip through incisions ranging in size from 1.2 to 1.6 mm. As expected, larger incisions generated less heat, and the temperature difference was significant (Figure 1). At 100% power and 12-mL/min flow, temperature ranged from 42.9º C with a 1.2-mm incision to 28.6º C with a 1.6-mm incision. This effect is attributable to the fact that the looser interface between the two surfaces (tissue and tip) produces less friction and, therefore, less heat. In addition, a larger incision allows greater leakage around the tip and therefore has a cooling effect. Based on these data, a very small, tight incision increases the risk of thermal injury.

Ultrasound Power

Ultrasound power varied between 50% and 100% through a 1.4-mm incision at a flow rate of 12 mL/min. As expected, the lower ultrasound power (stroke) resulted in less friction and a lower temperature at the incision (Figure 2). Temperatures ranged from 27.8º C at 50% continuous power to 52º C at 100% continuous power. Efficient cutting without excessive power appears to be an optimal goal in microincisional phacoemulsification.

Duty Cycle

Another way to decrease the amount of energy generated is by modulating the ultrasound by using hyperpulse at a given duty cycle. I set the power at 100% and varied the duty cycle at 25%, 50%, and 75%. At a 25% duty cycle, the temperature increased to only 26.7º C after 10 seconds (Figure 3). This parameter must be understood by any surgeon interested in performing microincisional phacoemulsification.

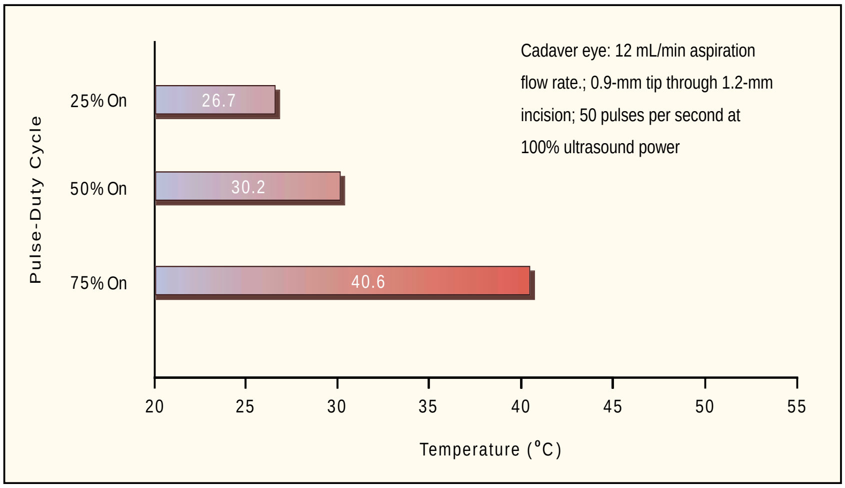

Figure 3. Elevated temperatures at the incision site were observed with a higher pulse-duty cycle at 10 seconds.

Aspiration Flow Rate

During microincisional phacoemulsification, primary cooling is due to the aspiration flow rate within the needle, while incisional leakage outside the needle provides secondary cooling. In vitro results show that, the greater the unobstructed aspiration flow is, the cooler the tip is (Figure 4). An increase in the aspiration rate, however, must be balanced with maintenance of the chamber depth.

Occlusion

Thermal injury to the incision site usually occurs during the occluded state when there is a cessation of aspiration flow. Visco-obstruction probably is one of the most common causes of thermal injury. Although high-viscosity viscoelastics are more prone to producing high temperatures at the incision, I evaluated temperature increase under the worst-case condition of total occlusion. Even when the aspiration line was completely occluded with a hemostat, a considerable reduction in

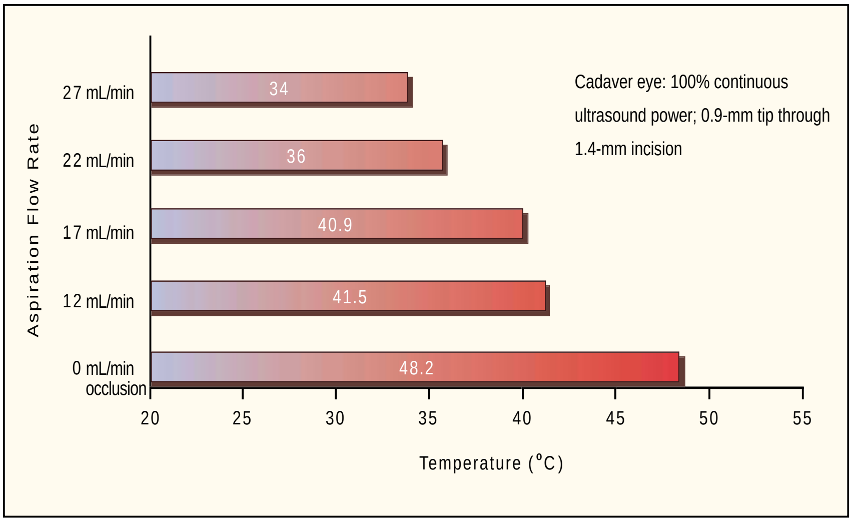

Figure 4. Lower aspiration flow rates produced higher incisional temperatures at 10 seconds.

temperature was observed at the incision when I used hyperpulse at a 25% duty cycle.

Vacuum Limit

Vacuum limit varied from 0 to 200 mm Hg. The study demonstrates that, when vacuum limits are set too low, higher temperatures can occur at the incision. For example, at 25 mL/min with a 0.9-mm tip in a 1.2-mm incision at 80% power, the temperature increased from 31.5º to 39º C when the vacuum limit was decreased from 150 to 50 mm Hg. This effect is not necessarily intuitive. Vacuum limit influences the temperature at the incision by indirectly affecting the flow rate. Aspiration flow in a restrictive lumen will generate a certain level of vacuum. If the vacuum limit is set too low, the effective aspiration flow will be reduced so that the vacuum preset is not exceeded. Raising the vacuum level too high, however, may produce surge and chamber instability.

Tip Size

Although a large tip allows more cooling flow than a small one, I found that a 0.9-mm tip (tapered microtip) produced less thermal energy than a 1.1-mm tip when the incision size was constant. A fixed incision is more favorable to smaller tip diameters, which may be explained in terms of less friction and, perhaps, more leakage around the tip. In a clinical setting, the more favorable temperature profile of a smaller tip must be balanced against less efficient cutting and more nuclear chips. In addition, a slightly larger incision may be required to accommodate a larger tip.

Additional Parameters

Insignificant changes in temperature at the incision site were observed in relation to the temperature of the BSS (chilled vs room temperature), bottle height, and pulse frequency.

CONCLUSION

Safe microincisional phacoemulsification is contingent upon the effective management of heat generated by the bare ultrasound tip at the incision site. Mechanical stress at the incision site and poor fluidics (due to incisional leakage and low irrigation flow) can also negatively affect surgical outcomes. Although these concerns are valid, this study specifically focused on the thermal effects of the procedure.

These in vitro findings indicate that microincisional phacoemulsification can be performed at a safe temperature with knowledgeable and careful selection of surgeon-controlled parameters. Greater temperature increases at the incision were associated with smaller, tighter incisions, higher ultrasound power, a higher duty cycle, lower aspiration flow rates, and lower vacuum limits. Although BSS temperature, bottle height, and pulse frequency are important parameters for surgical outcomes, they did not seem to be significant in terms of their effect on the incision's temperature.

As cataract surgery continues to evolve, the use of smaller incisions seems inevitable, especially once high-quality IOLs that can be inserted through microincisions become available. Nonetheless, our profession's enthusiasm must be tempered by the high priority of patient safety. For now, coaxial phacoemulsification is my procedure of choice. ■

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