

Reduction of Corneal Burns Risk with Programmable Emission Mode in Phacoemulsification

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The purpose of the present work is to evaluate the temperature variations into the corneal incision and inside the anterior chamber of the eye during the phacoemulsification procedure in the cataract surgery. In phacoemulsification many new surgical techniques have been introduced, among which several new patterns for ultrasound emission, the aim being to reduce the energy needed to crush the cataract and, therefore, the mechanical and thermal damages to the surrounding structures of the eye. All modern ultrasounds (US) handpieces use a piezoelectric crystal which converts electrical energy into mechanical oscillation, that is used to emulsify the crystalline lens of the eye. The axial oscillation frequency of the tip is between 27.000 and 40.000 cycles per second; because of this oscillation, there is a friction between the phaco tip and the silicone sleeve that generates heat. This is transferred to the incision by thermal conduction and into anterior chamber by conduction and convection. The purpose of this work is to correlate the thermal changes in the eye to various patterns of ultrasound emission, more specifically, traditional patterns and the ones designed with the new Programmable Emission Mode (PEM).

Methods

An artificial neoprene cornea has been designed that has the same elasticity and dimensional properties of a real human cornea. The Neoprene is, in literature, the elastomer that is closest, for elastic behavior and other physical properties, to the “in vivo” corneal tissue.

<i>Elastic factors of corneal model</i>	
Young module	1MPa
Hardness	30 ShoreA
Poisson factor	0.49
Volumetric strength	16.6MPa
Transversal strength	0.335MPa

The eye simulator illustrated in figure 1 has been used.

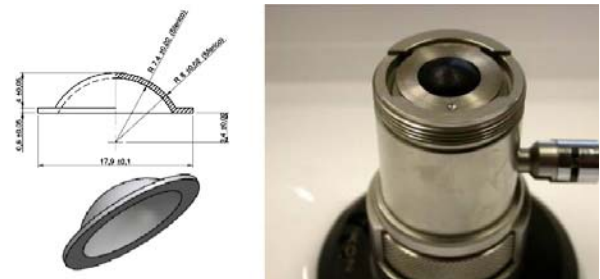


Figure 1: Axonometric view and dimensions of neoprene spherical cap with mechanical device to insert artificial cornea.

Neoprene spherical cap is inserted into a mechanical device which reproduces both anterior eye chamber volume (0.4cc) and the boundary adhesion of the cornea onto the sclera.

A thermocouple has been connected to an electronic equipment that conditions its electrical signal, which is then sent to a PC by a microcontroller using serial protocol. The accuracy of this system is 0.2°C, however, all results have been approximated via software to 1°C resolution.

The real time values of all operating parameters, such as phaco power, aspiration flow, vacuum and irrigating pressure, are measured by the Phaco equipment and delivered to the PC via the Video overlay connection. All data have been sampled and saved with a sampling rate of 10Hz, using a custom software developed at Optikon.

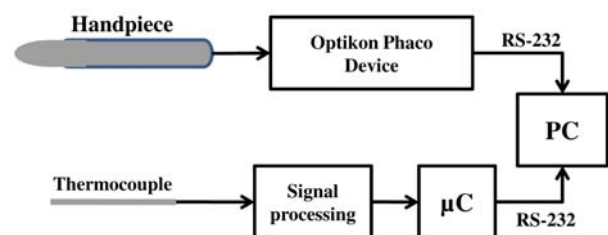


Figure 2: Block diagram of the experimental data acquisition.

All tests have been performed with a “Slim 4” Optikon phaco handpiece, with a standard 20G tip, and a silicone 20G sleeve. The incision has been done with a 2.6mm precalibrated phaco knife.

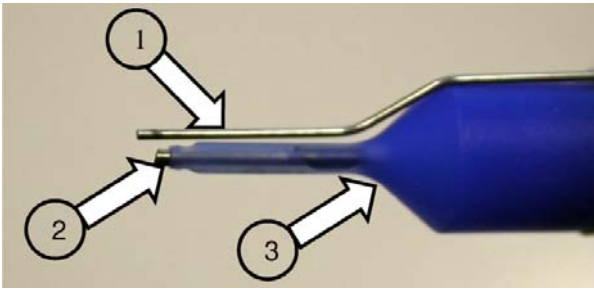


Figure 3: View of the phaco tip (2), the sleeve (3) and the shaped thermocouple (1).

Figure 3 shows the first experimental method with the tip, the sleeve and the shaped thermocouple. The insertion of the thermocouple into the incision on the artificial cornea with sleeve and phaco tip causes small leakage of balanced saline solution (BSS).

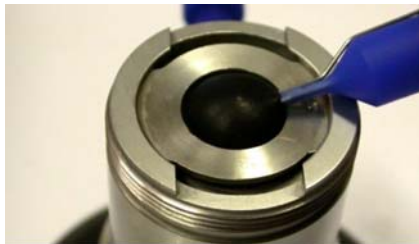


Figure 4: Photo of the surgical handpiece inserted into the 2.6mm incision.

Figure 5 shows the second experimental method on a second neoprene spherical cap. A 2.6mm incision has been effected to insert tip and sleeve. A service hole was used to insert the thermocouple which measured the temperature inside the artificial eye chamber.

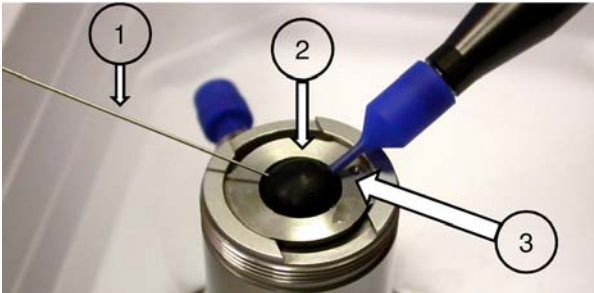


Figure 5: View of the thermocouple (1), artificial cornea (2) and phaco tip with sleeve (3).

The Optikon phaco device has been set with a 250mmHg vacuum in peristaltic pump mode, and an irrigation flow of 26cc/min. The tests have been performed at various heights of the bottle of BSS and various Power/Mode of ultrasounds emission. The tests have been performed in standard ambient condition (temperature 25°C, pressure 1Bar, and humidity 40%). Average time of US emission was 2 seconds. The height of the BSS bottle is measured between eye simulator level and the level of the drip chamber.

Results

The following graphs represent trend of temperature in function of time, power, and aspiration flow.

Continuous Emission Mode

Set the emission in continuous mode, 35% Power, bottle height of 55cm. The temperature measured inside the anterior chamber rises from 27°C to 33°C in less than 1 second (Fig. 6).

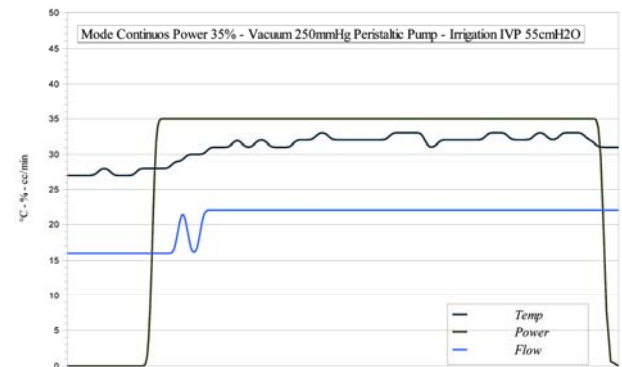


Figure 6.

Increasing the power to 40% and irrigation height to 86cm, the temperature on the tip of the sleeve rises more slowly at the beginning of US emission, but then grows quickly from a temperature of 26°C to 38°C (Fig. 7).

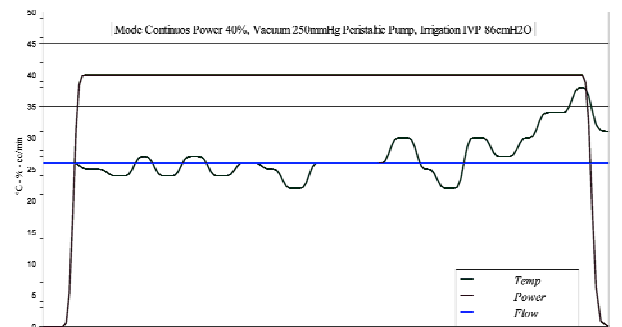


Figure 7.

In the following graph it is possible to see that raising the height of the BSS bottle at the remarkable value of 122cm, with the power set at 100%, the temperature inside the anterior chamber reaches significant values with a constant temperature growth ratio starting from 29°C and reaching 40°C in less than a second. This value remains stable until the US emission is stopped (Fig 8).

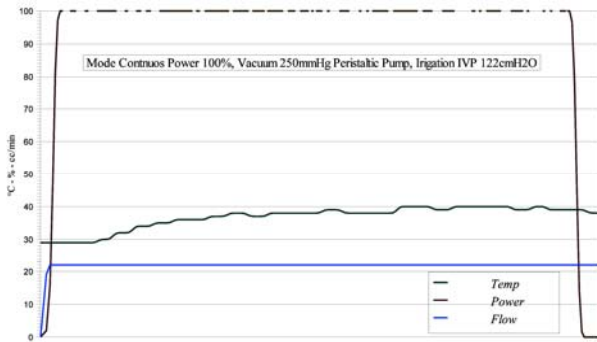


Figure 8

Single Pulse Mode

Setting the Single Pulse emission mode with a 5.4 Hz frequency, 100% power (duty cycle 50%), height of irrigation at 55cm, it is possible to observe as the growth ratio on the tip of the sleeve is more “soft” than in previous tests. The temperature, starting from 30°C, reaches nevertheless a value of 40°C (Fig 9).

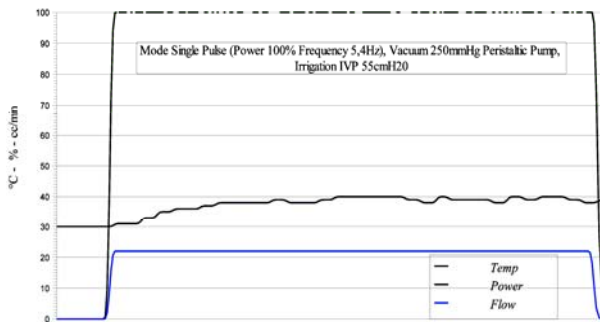


Figure 9

If test is repeated in the same configuration, changing the height of the bottle to 122cm, the temperature rises sharply in the first part of the graph, and the progress remains constant because the energy emitted per unit of time is lower than previous emission modes. The temperature starts at 30°C and reaches a steady value of 36°C (Fig 10).

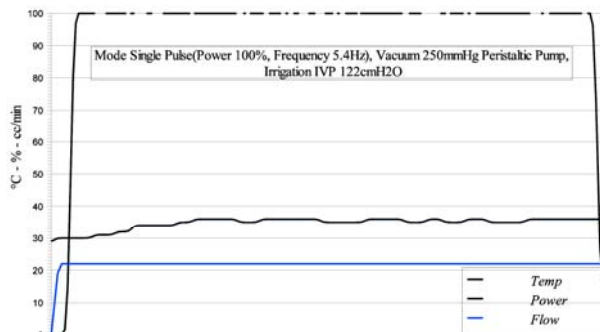


Figure 10

Programmable Emission Mode (PEM)

The emission values have been set as in figure 11.

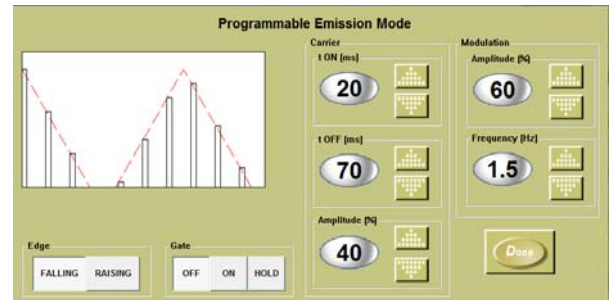


Figure 111

In the test the thermocouple has been positioned on the sleeve tip, the power has been set to 100%, and the bottle height was 55cm. In this configuration, during the US emission time (2 seconds), the average temperature of the artificial anterior chamber was 25°C, the same of the BSS (Fig 12).

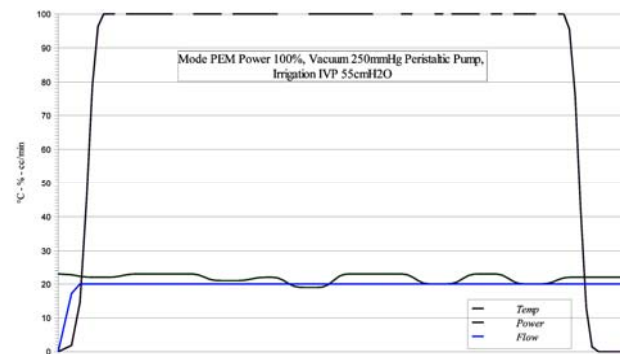


Figure 122

The last test has been run heating BSS bottle to 29°C, with an height bottle of 122cm. The power has been kept at 100% for 2 seconds; the temperature remained constant, and the energy emitted heated the anterior chamber and incision only marginally (Fig 13).

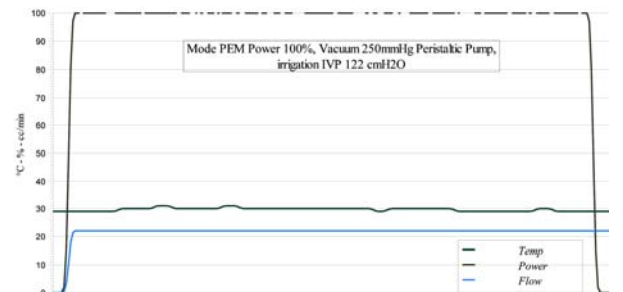


Figure 13

Conclusion

Part of the ultrasound energy delivered during phacoemulsification procedure causes an increase of the temperature in the anterior chamber. The power set and the pattern used to deliver the power affects this increase of temperature.

As the BSS from the irrigating source supplies cool liquid to the eye, the actual temperature depends on the aspiration flow rate and on the bottle height (an higher bottle causes more leakage from the incision and, therefore, a lower temperature).

Although not tested in the present experiment, it is expected that a temporary interruption of the aspiration (occlusion) may cause a significant temperature increase.

As far as the pattern used for ultrasound emission, the worst results (higher temperature increase) are in continuous ultrasound mode.

Slightly better outcome (smaller temperature increase) results in pulsed mode.

With PEM, an emission patterns may be configured that do not cause any significant thermal effect in the anterior chamber.