Effect of bottle height on the corneal endothelium during phacoemulsification

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PURPOSE: To directly measure intraocular pressure (IOP) in simulated phacoemulsification and to assess the usefulness of lowering the bottle height in protecting the corneal endothelium in clinical phacoemulsification.

SETTING: Nippon Medical School Hospital, Tokyo, Japan.

METHODS: Simulated phacoemulsification was performed in porcine eyes with 2 bottle heights, 65.0 cm (BH 65 group) and 19.0 cm (BH 19 group). The IOP was continuously measured with a microprobe. In a clinical study, phacoemulsification was performed with a bottle height of 60.0 cm (BH 60 group) and of 30.0 cm (BH 30 group). One day, 1 week, and 1 and 3 months after surgery, cell density and corneal volumes were measured using specular microscopy and rotating Scheimpflug photography, respectively.

RESULTS: In the simulation study, IOP fluctuated between 50 mm Hg and 60 mm Hg in the BH 65 group and between 20 mm Hg and 30 mm Hg in the BH 19 group. In the clinical study of 31 eyes, the rate of cell density decrease was significantly lower in the BH 30 group than in the BH 60 group at all time points. The rate of increase in corneal volume was significantly lower in the BH 30 group than in the BH 60 group at 1 month.

CONCLUSIONS: Intraoperative IOP in phacoemulsification with a usual bottle height appeared to exceed the normal range. Phacoemulsification with a low bottle height was less harmful to the corneal endothelium.

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The corneal endothelium can be damaged during phacoemulsification by factors such as excessive duration of phacoemulsification[1–3]; localized temperature increases[4]; or damage from lens nucleus fragments caused by the turbulent flow of the irrigating solution,[5,6] air bubbles,[7,8] or free radicals associated with ultrasound oscillation.[9–13] However, little attention has been paid to intraocular pressure (IOP) during surgery as a cause of corneal endothelial damage. Intraoperative IOP is determined by a balance between the irrigating (influx) pressure, which depends on the height of the irrigating bottle, and the outflow volume, which depends on the vacuum pressure, aspiration rate, and fluid leakage from the incision cite. Thus, the intraoperative IOP at one moment can be considered an instantaneous measure of the fluid flow into the anterior chamber.

Although turbulent flow of the irrigating solution is a known cause of corneal endothelial damage,[5,6] it has been discussed mainly in terms of the lens nucleus colliding with the corneal endothelium. The effect of elevated IOP or alteration of intraoperative IOP on the corneal endothelium has not been fully elucidated. In this study, we directly measured intraoperative IOP in simulated phacoemulsification in animal eyes and evaluated the effect of lowering the bottle height on corneal endothelial damage in clinical phacoemulsification.

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MATERIALS AND METHODS

Simulation Study

Phacoemulsification was performed in porcine eyes obtained from a local abattoir using a Sovereign WhiteStar system (Abbott Medical Optics). The surgery was performed via a superior 2.4 mm sclerocorneal incision with an aspiration rate of 22 mL/min and a vacuum pressure of 150 mm Hg. Two bottle height settings, 65.0 cm (BH 65 group) and 19.0 cm (BH 19 group), were used. Because the bottle height value that is set and displayed by the phaco device is not the true distance from the eye but is the distance from a certain point of the device to the bottle, actual distances from the eye to the bottle (true bottle height) were measured and found to be 88.0 cm in the BH 65 group and 40.5 cm in the BH 19 group. Intraoperative IOP was measured using a universal pressure meter (DPM-2 Plus, Fluke Corp.). The microprobe of the device was inserted from the 6 o'clock limbus into the anterior chamber, and the IOP was recorded continuously during the procedure.

Clinical Study

The clinical study included patients who had phacoemulsification and intraocular lens implantation over a 3-month period starting in November 2005 at Nippon Medical School Hospital. In all cases, lens nucleus hardness was approximately 2 according to the Emery-Little classification.

The same surgeon (H.S.) operated on all patients using the same type of phaco system used in the simulation study. Phacoemulsification was performed through a superior sclerocorneal incision using sodium hyaluronate 2.3% (Healon5), an ultrasound power output of 20%, and vacuum pressure of 150 mm Hg. Two bottle height settings, 60.0 cm (BH 60 group) and 30.0 cm (BH 30 group), were used; both bottle heights were displayed on the device. These settings were different from those in the simulation study. The reason is that a bottle height of 19.0 cm was considered too low and there was concern that it may cause anterior chamber collapse in clinical phacoemulsification; in addition, the 60.0 cm height is the standard setting used at the hospital where the surgery was performed. The aspiration rate was set at 20 mL/min in the BH 60 group and 18 mL/min in the BH 30 group to prevent anterior chamber collapse.

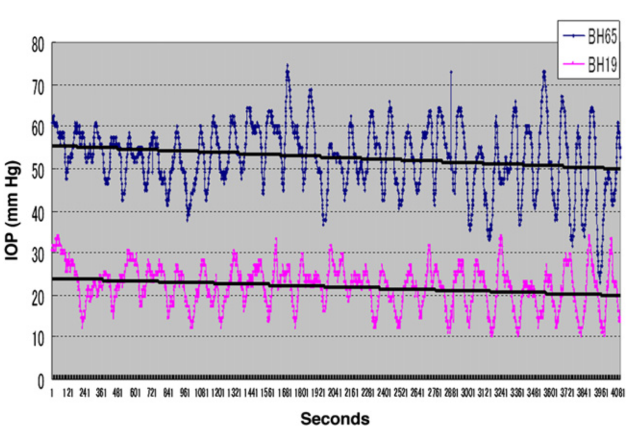

Figure 1. Intraoperative IOP in the BH 65 and BH 19 groups. In the BH 65 group, intraoperative IOP oscillated between 50 mm Hg and 60 mm Hg and in the BH 19 group, between 20 mm Hg and 30 mm Hg (BH19 = bottle height at 19.0 cm; BH65 = bottle height at 65.0 cm; IOP = intraocular pressure).

A specular microscope (Noncon Robo, Konan Medical) and a rotating Scheimpflug camera (Pentacam, Oculus) were used to analyze the cornea before surgery and 1 day, 1 week, and 1 and 3 months after surgery. Specular microscopy was performed in the central cornea to measure cell density and to analyze polymegathism (coefficient of variation) and pleomorphism (hexagonal cell ratio 6A) using the center method. The Scheimpflug camera was used to calculate the corneal volume within 3.0 and 10.0 mm circles in the central cornea.[14,15]

Statistical analysis was performed using the unpaired Student *t* test, F test, 1-way analysis of variance (ANOVA), or Dunnett test, when appropriate.

RESULTS

Simulation Study

The intraoperative IOP fluctuated in an oscillating fashion (Figure 1). The IOP in the BH 65 group (mean 52.72 ± 7.94 mm Hg) was statistically significantly higher than in the BH 19 group (mean 21.96 ± 4.98 mm Hg) ($P<.05$, Student *t* test). Moreover, the range between the maximum IOP and minimum IOP was significantly greater in the BH 65 group than in the BH 19 group ($P<.05$, F test).

Clinical Study

The clinical study comprised 63 patients (63 eyes); there were 31 patients in the BH 60 group and 32 patients in the BH 30 group. In all cases, the surgery lasted fewer than 20 minutes and the effective phaco time was generally fewer than 10 seconds.

At all time points, the rate of cell density decrease was statistically significantly lower in the BH 30 group than in the BH 60 group ($P<.05$, ANOVA and Dunnett test) (Figure 2). No significant difference was observed in the coefficient of variation and hexagonal cell ratio between 2 groups at any time point.

Figures 3 and 4 show the rate of corneal volume increase compared with the preoperative value. One

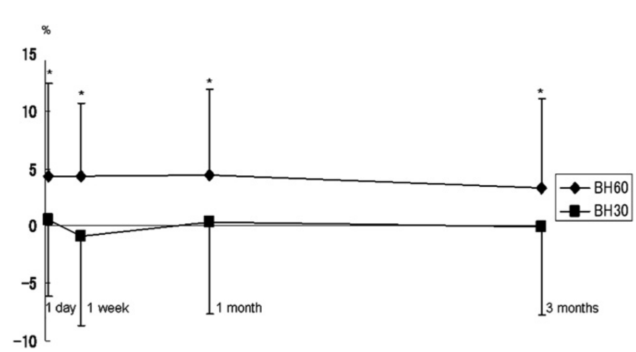

Figure 2. Rate of cell density decrease (* = $P<.05$, ANOVA and Dunnett test; BH30 = bottle height at 30.0 cm; BH60 = bottle height at 60.0 cm).