Comparison of Vacuum and Aspiration on Phacoemulsification Efficiency and Chatter Using a Monitored Forced Infusion System

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• PURPOSE: To evaluate the effect of vacuum and aspiration rates on phacoemulsification efficiency and chatter using a monitored forced infusion system.
• DESIGN: In vitro animal study.
• METHODS: SETTING: John A. Moran Eye Center, University of Utah, Salt Lake City, Utah. PROCEDURES: Formalin-soaked porcine lenses were divided into 2 mm cubes (tip diameter, 0.9 mm). Vacuum levels were tested at 200, 300, 400, and 500 mm Hg; aspiration rates at 20, 35, and 50 mL/min. Torsional power was set at 60% and intraocular pressure at 50 mm Hg.
• RESULTS: Increasing vacuum increased efficiency regardless of aspiration rates ($R^2 = 0.92$; $P = .0004$). Increasing aspiration further increased efficiency when vacuum was at 400 and 500 mm Hg ($P = .004$ for 20 vs 35 mL/min, $P = .0008$ for 35 vs 50 mL/min). At 200 and 300 mm Hg, efficiency only improved when increasing aspiration to 35 mL/min ($P < .0001$ with 20 vs 35 + 50 mL/min). Chatter improved with increasing vacuum, up to 400 mm Hg ($P = .003$ for 200 vs 300 mm Hg and $P = .045$ for 300 vs 500 mm Hg). A similar trend of improved chatter was seen with increasing levels of aspiration.
• CONCLUSIONS: Vacuum improved efficiency up to 500 mm Hg independent of flow. Flow has an additive effect on efficiency through 50 mL/min, when vacuum is at 400 mm Hg or higher, and only up to 35 mL/min at vacuums less than 400 mm Hg. Chatter correlated with both vacuum and flow such that increasing either parameter decreases chatter, up to 400 mm Hg with vacuum. (Am J Ophthalmol 2016;169:162–167. © 2016 Elsevier Inc. All rights reserved.)

PHACOEMULSIFICATION (PHACO) TECHNOLOGY HAS rapidly developed since its introduction in 1967.[1] High-frequency ultrasound and tip movement are used to emulsify the cataracts; then, aspiration and vacuum are used to remove the lens material. The efficiency, small incision, and safety of this procedure has improved patient outcomes; however, a desire for greater efficiency and safety has led to new machines with many new features.[2]

One such feature of the CENTURION Vision System (Centurion; Alcon Surgical, Fort Worth, Texas, USA) is monitored and controlled intraocular pressure, which is thought to improve chamber stability and improve safety.[3,4] This means the Centurion system has a pressurized infusion ability, whereby an operator can set the intraocular pressure to be maintained so that the flow is no longer gravity dependent. The addition of this new setting to the vast range of options can present challenges; consequently, knowing which settings are optimal is usually based on clinical intuition. This study, which serves to objectively define optimal setting parameters, is based on another study in which we determined that the optimal torsional setting is 60% power when assessing efficiency and chatter.[5] We now evaluate optimal flow and vacuum settings.

METHODS

THIS WAS AN EXPERIMENTAL STUDY INVOLVING ANIMAL research.

• PORCINE LENS PREPARATION: Porcine lenses were prepared as previously described.[6] Briefly, whole pig eyes (Visiontech Inc, Sunnyvale, Texas, USA) were dissected within 48 hours of arrival. Lens nuclei were fixed individually in 10 mL of 10% neutral buffered formalin for 2 hours and then washed 3 times with balanced salt solution (BSS). The lenses were then placed at room temperature in BSS for 24 hours. Subsequently, the porcine lenses were cut into 2.0 mm cubes and then transferred to a container of BSS. The lens cubes were washed 3 times with BSS and again allowed to equilibrate in 10 mL of BSS until use.

• TESTING: Phaco of the individual lens cubes was done using the Centurion Vision Systems machine. All experiments were conducted using a balanced phaco tip with a 20 degree tip and a 30 degree bevel (Alcon Surgical). Because IOP would be meaningless in an open system,

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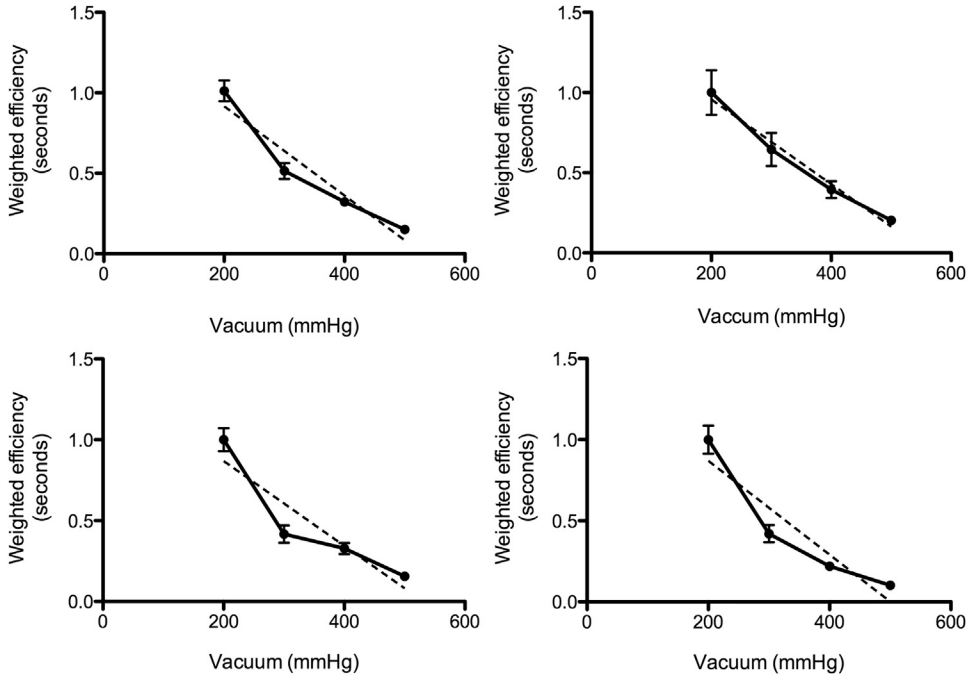

FIGURE 1. Effect of vacuum and aspiration on efficiency at 20 mL/min, 35 mL/min, and 50 mL/min combined (Top left) and at each individual aspiration level (Top right, 20 mL/min; Bottom left, 35 mL/min; Bottom right, 50 mL/min).

and consistent with our previous experiments, matching infusion sleeves were used to create a closed system. Torsional power was set at 60% and monitored forced infusion intraocular pressure (IOP) at 50 mm Hg. Though Centurion makes forced-infusion intraocular pressure a variable, we have previously shown that increasing IOP does increase efficiency and flow, especially when going from 30 to 50 mm Hg, so we picked 50 mm Hg to better compare efficacy and chatter.[7,8] Twenty runs, using a total of 20 lens cubes, were performed at each setting. We ran 20 trials for each of the following: aspiration at 20, 35, and 50 mL/min and vacuum at 200, 300, 400, and 500 mm Hg. In total, we ran $3 \times 4 \times 20 = 240$ trials. For each trial, the lens cube was engaged in the phaco tip using vacuum alone. The time from the start of phacoemulsification to complete lens removal was measured using a handheld stopwatch, by the same surgeon, for all 240 trials. Only the time the lens fragment was engaged at the phaco tip was recorded; that is, time started from when the lens was engaged and the pedal pressed and ended when the last piece of the lens disappeared. Time during chatter events, defined as the number of times the lens fragment dislodges from the tip so a surgeon has to stop and reengage the lens, was not counted as part of the total time. The recorded elapsed time was considered as the efficiency time. The chatter events were also recorded in each trial. The entire run was at 60% power, which we had previously been able to show was optimally efficient with the least chatter.[5]

• **STATISTICAL ANALYSIS:** Efficiency times were averaged and a standard deviation (SD) was calculated. Data points that were more than 2 SDs from the mean were considered outliers and removed in the final analysis. The removal of outliers is based on our previous work, which demonstrated that these lens fragments have the consistency of very hard human nuclei and so can add noise to the system by bouncing around on the needle tip for several seconds before the vacuum finally seals the piece and the piece is then promptly emulsified.[6] When picking cubes randomly, it is hard to avoid such outliers; so we adjusted for this by removing data points that are more than 2 SDs from the mean. New means and SDs were recalculated. A linear regression with a calculated R^2 was used to compare efficiency times in the groups that appeared to show a linear relationship and unpaired Student *t* testing was used for comparison of other discrete groups. For comparison of chatter events, means and SDs of total chatter events were similarly calculated and evaluated. Where values from different flow or vacuum were combined for comparison, a weighted average was used where the mean of the lowest vacuum or flow numbers was determined and all other numbers were computed as a ratio of this mean. All statistical analyses were performed using GraphPad Prism (GraphPad Software, Inc, La Jolla, California, USA). Using a Bonferroni correction, significance was set at $P < .017$ owing to multiple comparisons.