ISSN: 2378-346X

Wright et al. Int J Ophthalmol Clin Res 2017, 4:077
DOI: 10.23937/2378-346X/1410077
Volume 4 | Issue 3
Open Access

International Journal of
Ophthalmology and Clinical Research

RESEARCH ARTICLE

Optimization of Venturi Mode Phacoemulsification Settings of the Abbott Medical Optics WhiteStar Signature Pro in a Porcine Lens Model

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Abstract

Objectives: To maximize efficiency and minimize chatter of the combined variables in venturi mode on the Abbott Medical Optics WhiteStar Signature Pro phacoemulsification machine with the Ellips FX handpiece.

Methods: In this *in vitro* laboratory study, porcine lens nuclei were hardened with formalin and cut into 2.0 mm cubes. Phacoemulsification was performed in runs of twenty porcine lenses at each setting. The study initially included runs in which power was set to 60%, vacuum 600 mmHg, and bottle height at 60 cm, 80 cm, and 100 cm. Then, three runs of twenty lenses with power at 60%, optimal bottle height from arm 1, and vacuum varied at 400 mmHg, 500 mmHg, and 600 mmHg were conducted. Finally, power was optimized with 6 runs at already-determined bottle height and vacuum settings, with incremental power variations from 50% to 100%.

Results: Efficiency increased with increasing bottle height. 80 cm was 27% faster than 60 cm (P = 0.00046) and 100 cm was 17% faster than 80 cm (P = 0.011). With increasing vacuum, efficiency also increased. 500 mmHg was 42% faster than 400 mmHg (P = 0.000015) and 600 mmHg was 14% faster than 500 mmHg (P = 0.017). Increasing power increased efficiency to 80%; subsequently, there was no efficiency gain. Efficiency increased by 47% between 50 and 80% power (P = 0.000029).

Conclusion: Optimal parameters to increase efficiency, using venturi mode on the WhiteStar Signature Pro, are a bottle height of 100 cm with vacuum at 600 mmHg and 80% power.

Keywords

Phacoemulsification, Venturi mode, Efficiency, Chatter

Introduction

The optimization of cataract surgery is becoming ever more important as the prevalence of cataracts continues to rise. By 2050, prevalence of cataracts is projected to double in the United States to around 50 million [1]. As the demand for cataract surgery continues to rise, it is increasingly essential to perform these surgeries efficiently and safely.

The equipment used to perform these surgeries is also advancing. With multiple companies making different types of machines with various claims of success, methods to objectively evaluate these products are needed. We have developed a way to test these machines in a consistent environment, and we have shown that our porcine lens model produces cataracts equivalent to 3 to 4 + human lenses [2].

In this study, we used the porcine lens model to further optimize the Abbot Medical Optics WhiteStar Signature Pro phacoemulsification machine. As this is one of the newer phacoemulsification systems on the market, it is important to ascertain the optimal settings for each mode. Having already optimized peristaltic mode [3], in this study we progressed to investigating venturi mode.

Methods

Porcine lens preparations

Lens preparation was done as described previously

Citation: Wright AJ, Thomson RS, Bohner AD, Bernhisel AA, Zaugg B, et al. (2017) Optimization of Venturi Mode Phacoemulsification Settings of the Abbott Medical Optics WhiteStar Signature Pro in a Porcine Lens Model. Int J Ophthalmol Clin Res 4:077. doi.org/10.23937/2378-346X/1410077

Received: April 06, 2017: **Accepted:** August 31, 2017: **Published:** September 02, 2017

[2]. Briefly, whole porcine eyes were ordered from Visiontech Inc. (Sunnyvale, TX, USA). Within 48 hours of arrival these eyes were dissected and intact whole lenses were placed in 10 mL of 10% neutral buffered formalin. The lenses hardened for two hours, after which time they were rinsed three times in 10 mL of Basic Salt Solution (BSS). They were incubated at room temperature in 10 mL of BSS for 24 hours; then they were cubed into 2.0 mm by 2.0 mm pieces. After cubing, the lenses were submerged in BSS until the studies were conducted [4]. Studies were conducted no longer than 24 hours after cubing was finished.

Phacoemulsification

This was performed on the Abbott Medical Optics (AMO) (Santa Anna, CA, USA) WhiteStar Signature Pro with the Ellips FX handpiece and a 0.9 mm bent Dewey tip with a 30-degree bevel (Microsurgical Technology Inc. Redmond, WA, USA).

Efficiency was measured as the total time in seconds to completely remove the lens fragment from the test chamber, beginning with ultrasound initiation. A lens fragment was placed in the test chamber. The foot pedal was partially compressed, utilizing vacuum only to bring the lens fragment to the tip. At this point, the pedal was fully compressed, initiating ultrasound, and time was begun. A stopwatch was used to measure efficiency from ultrasound initiation to complete fragment removal. Timing was paused when the fragment fell or bounced from the tip. In this way chatter delay was separated from efficiency. For this experiment a chatter event was defined as any time the lens fragment bounced from the tip during phacoemulsification.

There were three arms included in this study. The aim of the initial arm was to optimize bottle height. For this arm power was set to 60% and vacuum to 600 mmHg. Three runs of twenty porcine lens cubes were performed at bottle heights of 60 cm, 80 cm, and 100 cm. The second arm aimed to optimize vacuum. For this arm power was again set at 60% and bottle height was set at 100 cm, which had been determined to be the optimal bottle height during arm 1. Three runs of twenty porcine lens cubes were performed at 400 mmHg, 500 mmHg, and 600 mmHg. The final arm of the study aimed to optimize power. Again, bottle height was set at 100 cm and vacuum was set at 600 mmHg, which were determined to be the optimal settings during arm 2. Power varied from 50% to 100%, at increments of 10%, over six runs of twenty lenses per run.

Statistical analysis

Summary statistics (mean and standard deviation) were calculated for efficiency and chatter. Data points that fell outside of two standard deviations above and below the mean were removed from the data set. Previous research has shown that these lenses are either comparable to extremely hard human nuclei or take several seconds before setting on the tip and emulsifying quickly [2]. Due to these inconsistencies, findings are more accurate if these outliers are removed from the analysis. After they were removed, the summary statistics were recalculated. Analysis of Variance (ANOVA) was used to determine whether variance was present among the data sets. When variance was found, two factor t-tests assuming unequal variance were used to calculate P values. A P value less than 0.05 was considered significant. When analyzing the power data set, linear regression with calculated R squared values was also used. All statistical was analyses were performed using Microsoft® Excel version 15.3.

Results

Table 1 provides summary statistics for all testing runs. An 80 cm bottle height proved to be more efficient than 60 cm, with mean efficiency times of 0.61 seconds (s) and 0.84 s respectively (P = 0.00046). A 100 cm bottle height further increased efficiency when compared to 80 cm with a mean efficiency time of 0.512 s (P = 0.011) (Figure 1). ANOVA showed that the number of chatter events did not vary significantly between the three bottle heights, although 100 cm did have the least total number of events (P = 0.36).

Using the optimal bottle height of 100 cm, 500

Table 1: Summary statistics of phacoemulsification of 2.0 mm porcine lens cubes at varying bottle height, vacuum, and power settings.

Bottle height (cm)	Vacuum (mmHg)	Power (%)	Efficiency (s) ± SD	Chatter ± SD
60	600	60	0.841 ± 0.21	0.05 ± 0.22
80	600	60	0.614 ± 0.14	0.1 ± 0.31
100	600	60	0.512 ± 0.079	0 ± 0
100	400	60	0.897 ± 0.29	0.1 ± 0.31
100	500	60	0.519 ± 0.10	0.05 ± 0.22
100	600	60	0.445 ± 0.080	0.05 ± 0.22
100	600	50	1.27 ± 0.46	0.1 ± 0.31
100	600	60	1.22 ± 0.59	0.05 ± 0.22
100	600	70	0.971 ± 0.25	0 ± 0
100	600	80	0.678 ± 0.21	0 ± 0
100	600	90	0.78 ± 0.37	0 ± 0
100	600	100	0.739 ± 0.36	0 ± 0

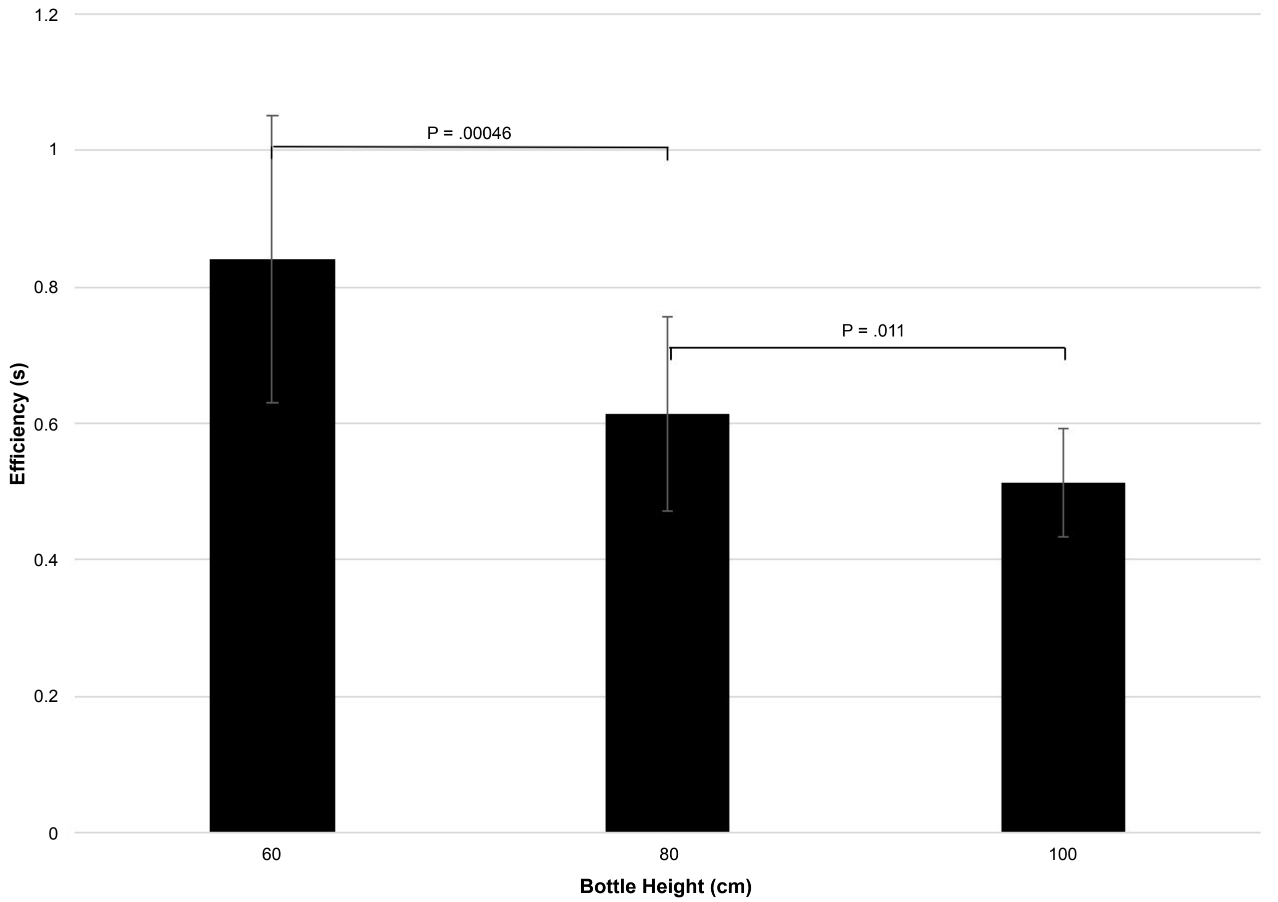

Figure 1: The mean efficiency, measured in seconds, of phacoemulsification of 2.0 mm porcine lens cubes at three bottle height settings.

mmHg, efficiency was significantly better than at 400 mmHg, 0.519 s and 0.897 s respectively (P = 0.000014). Efficiency further increased between 500 and 600 mmHg, 0.519 s and 0.445 s respectively (P = 0.017) (Figure 2). The number of chatter events did not vary significantly between the three vacuum settings (P = 0.77), but did trend downward with increasing vacuum.

Using linear regression with a calculated R^2, we showed that efficiency improved from 50% up to 80% power, with an R^2 of 0.93. Two-sided t-tests showed significant increases in efficiency between 50% and 80% power, 1.27 s and 0.678 s respectively (P = 0.000029). There was also a significant increase in efficiency between 70% and 80% power, 0.971 s and 0.678 s respectively, (P = 0.00053) (Figure 3). After 80%, there was no significant increase, and possibly a slight decrease in efficiency. The R^2 value between 80 and 100% was 0.37. T-tests confirmed non-significant changes for this range (P = 0.32 between 80 and 90%; P = 0.75 between 90 and 100%). ANOVA showed non-significant changes in chatter events throughout the range of power settings. The total number of chatter events decreased from 50 to 70% power, after which it remained constant.

Discussion

The goal of this experiment was to optimize venturi settings in order to improve efficiency and safety. Decreasing the amount of energy needed by maximizing efficiency helps to reduce the rate of complications [5-8]. Some of these complications include incisional burn, corneal edema, capsular breakage, and endothelial damage.

The venturi pump system functions using the venturi effect, which creates vacuum by the flow of a fluid, often air, over an opening. This generates suction out of a rigid cassette that is connected to the phaco aspiration tubing. The benefit of the venturi system is its ability to reach maximum vacuum levels without occluding the tip. For this reason, it is often referred to as the vacuum model. The major downside of this system is its inability to control outflow parameters [9].

We saw that efficiency increased and the number of chatter events decreased with increased bottle height. As the bottle height increases, the infusion pressure and flow increases. This in turn would help stabilize the intraocular pressure and increase the hold of the lens fragments on the tip. Consequently, we saw a 27% increase in efficiency between 60 cm and 80 cm. Between 80 cm and 100 cm, the efficiency increased another 17%. Since 100 cm provided the greatest efficiency and least number of chatter events, this bottle height was chosen as the optimal parameter.

As expected, we also saw increased efficiency and a

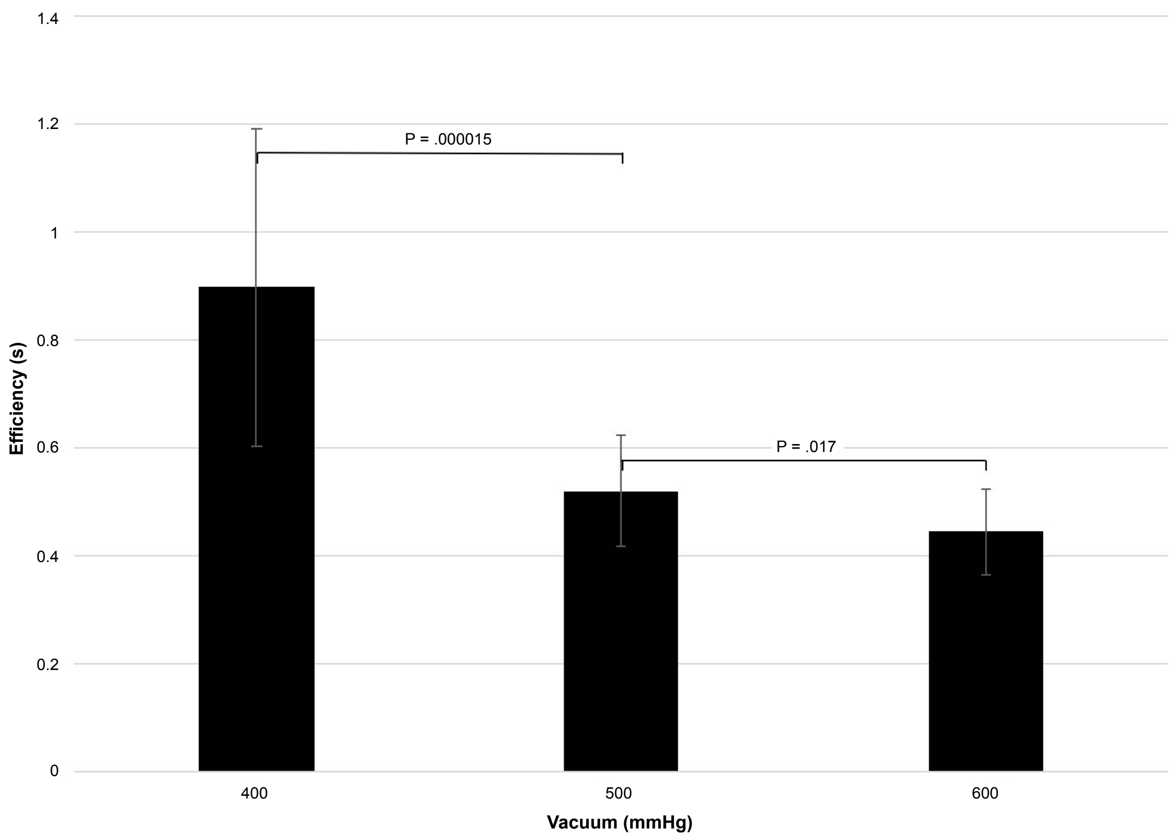

Figure 2: The mean efficiency, measured in seconds, of phacoemulsification of 2.0 mm porcine lens cubes at three vacuum settings.

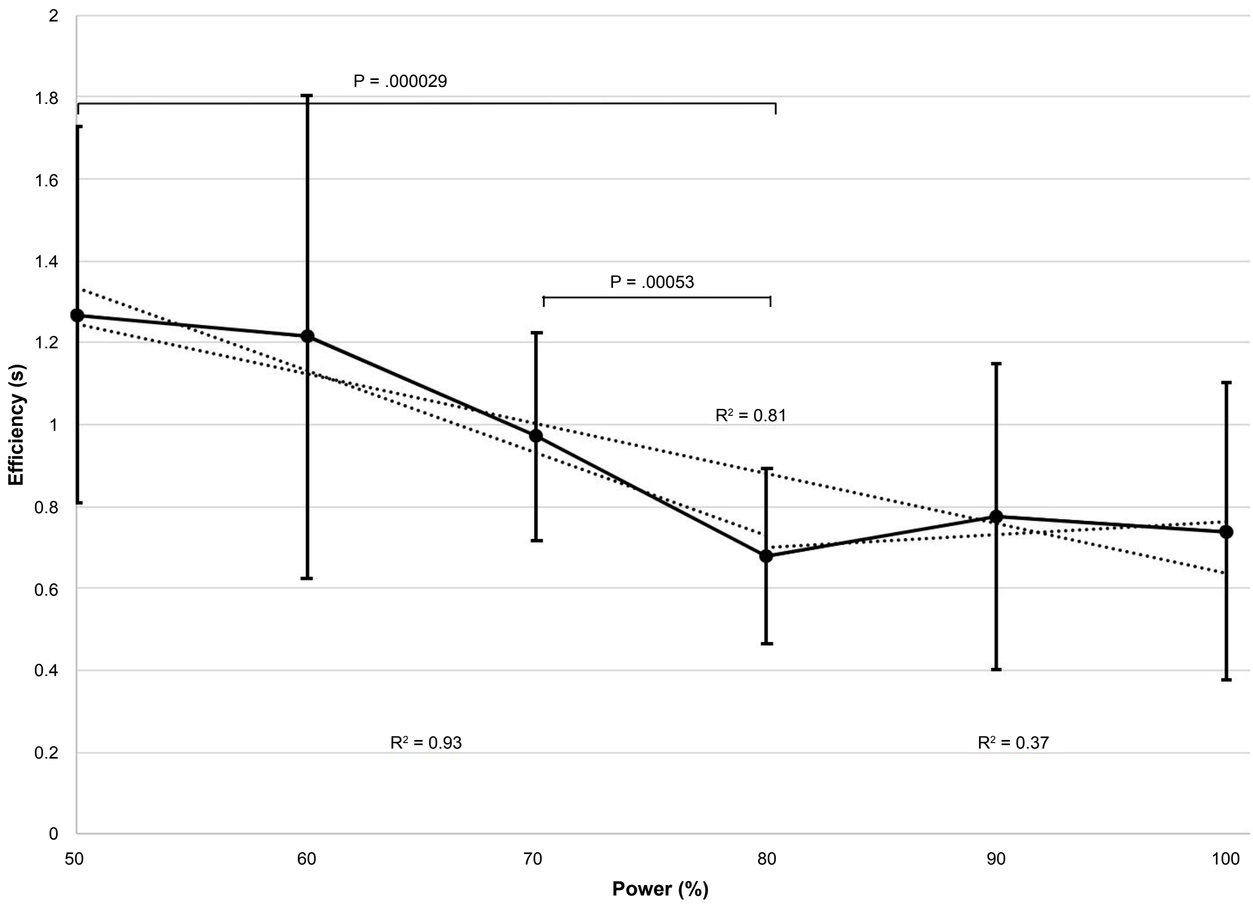

Figure 3: The mean efficiency, measured in seconds, of phacoemulsification of 2.0 mm porcine lens cubes at six power settings.

decrease in the number of chatter events as vacuum increased. As vacuum increases, the hold on the tip also increases. We saw a 42% increase in efficiency between 400 and 500 mmHg and a 14% increase in efficiency between 500 and 600 mmHg. There was a decrease in the number of chatter events as vacuum increased, but the infrequency of these events led to a non-significant difference among the three groups. Due to the decreased phacoemulsification time and similar occurrence of chatter, 600 mmHg of vacuum was selected as the optimal parameter.

It is noteworthy that the efficiency did not occur when power increased to beyond 80%. The reason for this finding probably is fluid turbulence at the tip, which disrupts the seal of the lens fragment to the tip and counters the usual increased efficiency with more power.

Power controls the amount of ultrasound energy utilized; and with increasing power, we would expect an increase in efficiency. In our experiment, this was true up to 80%. Between 50 and 80% power, there was a 47% decrease in phacoemulsification time. Notably, there was also a significant difference between 70 and 80% power. This 10% in power increase represented a 30% decrease in phacoemulsification time. After 80%, there was no gain in efficiency for the additional power used. Since power increases heat production and the potential for comorbidities, we do not recommend increasing power beyond 80%.

The major limitation of this study is its *in vitro* design. It would be ideal to test the parameters in a clinical setting, but this is difficult to do safely while having the same control we were able to achieve in this study. Specifically, in a clinical setting there would be concern about an increased complication rate while testing aggressive surgical parameters.

In conclusion, we found that bottle height, vacuum and power settings directly affect the efficiency and number of chatter events. We found that a bottle height of 100 cm, with vacuum set to 600 mmHg and power at 80 percent are the optimal parameters to optimize efficiency and decrease chatter. The effects of these parameters on safety issues such as post-occlusion surge are areas we are considering for future study.

Acknowledgement

This study was supported in part by an unrestricted grant from Research to Prevent Blindness, Inc., New York, New York, USA, to the Department of Ophthalmology and Visual Sciences, University of Utah, Salt Lake City, Utah, USA; and by Dr. Zaugg's Achievement Reward from the College Scientists Foundation Scholar program (ARCS Foundation Utah, Salt Lake City, Utah, USA). The tips used for this study were donated by Alcon Surgical (Fort Worth, Texas, USA).

Conflicts of Interest

None.

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