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· Clinical Research ·

Comparing surgical efficiencies between phacoemulsification systems: a single surgeon retrospective study of 2000 eyes

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Abstract
● **AIM:** To compare under similar conditions intraoperative surgical efficiencies metrics between an active fluidics and a gravity based phacoemulsification systems.
● **METHODS:** Adult patients who were diagnosed with a cataract that compromised visual acuity inferior to 20/40 were included in the study. Patients were excluded from the study if they had a history of severe retinal disorders, clinically significant corneal endothelial dystrophy or history of corneal disease. All phacoemulsification surgeries were performed by a single surgeon. Both phacoemulsification systems used the 0.9 mm 45-degree aspiration bypass system Intrepid Balanced tip and the 0.9 mm Intrepid Ultra infusion sleeve. All cataracts were classified using the Lens Opacities Classification System III, cumulative dissipated energy (CDE) and aspiration fluids were measured in each surgery.
● **RESULTS:** Totally 2000 eyes were included in the study. Phacoemulsification was performed in 1000 (50%) eyes with an active fluid dynamics system and in 1000 (50%) eyes with a gravity-based fluidic system. Mean CDE until fracture of the lens was 1.1 and 1.9 percent-seconds and total mean CDE used was 5.6 and 7.2 percent-seconds using an active fluidics dynamics system and gravity-based fluidic system, respectively ($P<0.001$). Mean aspiration fluids used were 70 mL using an active fluidics dynamics system and 84 mL using a gravity-based fluidic system ($P<0.001$).
● **CONCLUSION:** This study evidences that surgeries performed under similar conditions (same surgeon, phaco tip and sleeve) with the active fluidics dynamics system required significantly lower CDE and aspiration fluids.

● **KEYWORDS:** ophthalmology; phacoemulsification; surgical efficiencies; cumulative dissipated energy; aspiration fluids
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INTRODUCTION

Age-related cataract is the most common cause of reversible blindness in the world[1], with its first successful extraction of a cataract performed by Jacques Daviel in 1747[2]. In 1967, Charles Kelman[2] introduced phacoemulsification, a technique that uses ultrasonic waves to break down the cataract. Surgical extraction of the natural lens has progressed along time, leading to more than 20 million cataract surgeries performed worldwide each year[1-2]. Phacoemulsification is the gold standard for cataract surgeries globally and breakthroughs in different systems, ultrasound tips and sleeves continue to improve surgical efficiencies and results[2].

Cumulative dissipated energy (CDE) is the total ultrasound used during surgery to break down a cataract. CDE used during phacoemulsification is delivered by different ultrasound tips, that use longitudinal and torsional displacement to improve efficiencies, decreasing energy and fluids used[3-4]. Better outcomes in phacoemulsification surgeries are determined by the amount of ultrasound energy and fluids delivered to the eye[5-6], lower ultrasound energy used during surgery results in less endothelial cell loss, less postoperative corneal edema and better immediate postoperative visual acuities[5].

Changes in aspiration and infusion flow rates can cause fluctuations in intraocular pressure (IOP)[7]. Wide fluctuations of IOP may cause the anterior chamber to collapse and damage the cornea, the iris, and the lens capsule[7]. Phacoemulsification systems such as active fluid dynamics and gravity-based fluidic, are used to perform cataract surgeries. Active fluid dynamics systems apply or release bag pressure in response to varying irrigation, to maintain a target IOP during surgery despite varying aspiration flow rates[7]. Maintaining anterior chamber stability and decreasing fluctuations in IOP is essential to reduce complications and improve postoperative outcomes[7]. A study conducted by de Giacinto *et al*[8] demonstrated a statistically significant transient increase in IOP during femtosecond laser-assisted cataract surgery. Even though IOP values decreased and came back to preoperative values at 1d postoperatively, sudden increases of IOP can be dangerous for the ocular structures[8].

The purpose of this study was to compare intraoperative surgical efficiency metrics between two phacoemulsification systems under similar conditions as previous studies comparing phacoemulsification systems failed at comparing surgical efficiencies using different parameters, phacoemulsification tip and sleeve. CDE and aspiration fluids were compared between an active fluidics dynamic system and a gravity-based fluidic system configured with the same ultrasound tip and sleeve. Surgery was performed by a single surgeon to 2000 eyes, during routine phacoemulsification extraction of cataracts graded with the Lens Opacities Classification System III (LOCS III).

SUBJECTS AND METHODS

Ethical Approval This study was approved by the Institutional Ethics Committee of Research (Clínica Oftalmológica del Caribe, Barranquilla, Colombia) with code and number of approval CEFQX-01 and adhered to the Declaration of Helsinki's tenets.

Study Design This retrospective study of 2000 eyes was conducted in Barranquilla, Colombia from August 2017 to December 2019. A single surgeon operated all eyes and cataracts were graded using the LOCS III a standardized photographic comparison system for grading the features of the human age-related cataract[9].

Patients All consecutive cases of cataract extraction with phacoemulsification and intraocular lens (IOL) implantation were performed in a single ambulatory surgical center (Clínica Oftalmológica del Caribe, Barranquilla, Colombia). A total of 2000 eyes of adult patients who were diagnosed with a cataract were included in the study. The 1000 surgeries were performed using the Centurion Phacoemulsification System (active fluidics dynamic) and 1000 surgeries using the Infiniti Phacoemulsification System (gravity-based fluidic dynamics). All surgeries were performed by a single surgeon (Valdemarín B) and all patients were allocated randomly to each of the two systems depending on the operation room assigned. Both phacoemulsification systems were used to equal extent throughout the study period. The inclusion criteria were the following: patients diagnosed with cataract classified according to the LOCS III, corrected distance visual acuity (CDVA) inferior to 20/40 according to the Snellen Chart and individuals over 18 years of age. Patients were excluded from the study if they had a history of severe retinal disorders or detachment, clinically significant corneal endothelial dystrophy or history of corneal disease and ocular inflammatory conditions.

Surgical Technique Surgery was performed according to site-specific standard operating procedures following the next steps: 1) Clear corneal incisions with MVR-Lance 20G at 40 degrees. 2) Application of intracameral Roxicain and Epinephrine 1%. 3) Injection of Trepan Blue for 30s. 4) Injection of balanced salted solution and an ophthalmic viscosurgical device (OVD) sodium hyaluronate 1.4% (Bio-Hialur Plus). 5) Corneal incision of 2.75 mm at 140 degrees. 6) Continuous curvilinear capsulorhexis of 5.0 to 5.5 mm with an Utrata forceps was created. 7) Hidrodissection and hidrodelamination until rotation of the lens was performed. 8) Both phacoemulsification systems used the 0.9 mm 45-degree aspiration bypass system Intrepid Balanced tip and the 0.9 mm Intrepid Ultra infusion sleeve (data on file, Alcon Laboratories, 2017). 9) Phacoemulsification using vertical chop or horizontal chop was performed. 10) Aspiration of lens material and an OVD was applied to protect corneal endothelium: (hydroxypropylmethylcellulose 2%, Biocelulent). 11) Injection of the IOL provided by the institution. 12) Aspiration of the OVD and injection of intracameral antibiotic (moxifloxacin 0.5%). 13) Hydration of the incisions. 14) 10-0 nylon suture on main incision.

Phacoemulsification Parameters Parameters for phacoemulsification for the active fluidics dynamic system were set as follows: IOP 65-70 mm Hg, vacuum 350-575-400 mm Hg, aspiration flow rate 38-52-41 mL/min and 20%-75% torsional amplitude. Fluid parameters for the gravity-based system were vacuum limit 100-450 mm Hg, aspiration flow rate 40 mL/min, bottle height 70-90 cm. Ultra sound parameters were set at 20%-80% of torsional amplitude.

Both phacoemulsification systems used the same 0.9 mm 45-degree aspiration bypass system Intrepid Balanced tip and the 0.9 mm Intrepid Ultra infusion sleeve (Alcon Laboratories, 2017).

Outcome Measures CDE is displayed automatically on the Centurion (active fluidics dynamic system) and Infiniti (gravity-based system) interface and is measured in percent-seconds. The CDE was calculated using the same formula for the active-fluidics system and the gravity-fluidics system (CDE=average energy amplitude times duty cycle times time in foot position 3). The amount of CDE used was measured when the lens was fractured entirely, and when all fragments had been removed. Aspiration fluids (mL/min) used were recorded from the display on each phacoemulsification system's user interface. All cataracts were graded using the LOCS III classification system. Additionally, grade VII in the LOCS III was included to classify white cataracts for statistical analysis.

Statistical Analysis Descriptive statistics were used to analyze patients' characteristics. Efficiency times were averaged, and Standard Deviation (SD). An independent *t*-test was performed to analyze normally distributed variables and detect statistically significant differences between phacoemulsification systems regarding CDE and aspiration fluids delivered. A scatter plot with a trend line comparing CDE used between Centurion *vs* infiniti phacoemulsification system using the modified LOCS III classification system was performed. *P* values less than 0.05 were considered to be statistically significant. Statistical analysis was performed using the SPSS software (version 25; SPSS Inc., Chicago, IL, USA).

RESULTS

The study included 2000 eyes. Table 1 shows patient characteristics comparing both phacoemulsification systems. Phacoemulsification was performed in 1000 (50%) eyes with an active fluidics dynamic system and in 1000 (50%) eyes with a gravity-based fluidic system. Mean patient age was 69 years old for both systems. The 591 (59%) of patients operated with the active fluidics dynamic system and 554 (54%) of patients operated with the gravity-based fluidic system were female. Cataracts were graded with the LOCS III, 165 (16%) cataracts and 183 (18%) cataracts were graded between LOCS I and LOCS III in active fluidics dynamic system and gravity-based fluidic system, respectively. The majority of surgeries were performed on cataracts graded between LOCS IV and LOCS VI, 814 (81%) cataracts were operated using an active fluidics dynamic system and 789 (79%) cataracts were operated using a gravity-based fluidic system. White cataracts were classified as LOCS VII for analysis, 21 (2%) cataracts and 28 (3%) cataracts were operated using an active fluidics dynamic system and gravity-based fluidic system, respectively.

Table 2 shows a comparative analysis between phacoemulsification systems. Independent *t*-tests were performed to compare normally distributed variables. Mean CDE until fracture of the lens was 1.1 and 1.9 percent-seconds and total mean CDE used was 5.6 and 7.2 percent-seconds using an active fluidics dynamic system and gravity-based fluidic system, respectively ($P<0.001$). Both comparisons were calculated with a 95% confidence interval (CI). A reduction of 22% of CDE used was evidenced between phacoemulsification systems using the same tip and sleeve. Additionally, a reduction in the use of aspiration fluids was evidenced between phacoemulsification systems, mean fluids used were 70 and 84 mL using an active fluidics dynamic system and gravity-based fluidic system, respectively. A reduction of 16% of fluids used was evidenced using the active fluidics system ($P<0.001$).

Table 1 Patient characteristics in phacoemulsification systems

Characteristics	Active fluidics phacoemulsification system (*n*=1000)	Gravity fluidics phacoemulsification system (*n*=1000)
Age (y, mean±SD)	69±10	69±10
Gender		
Male	409	446
Female	591	554
Eye		
OD	520	522
OS	480	478
LOCS III		
I	37	28
II	52	58
III	76	97
IV	197	264
V	505	464
VI	112	61
VII	21	28
Complications	2	9

LOCS: Lens opacities classification system.

Table 2 Comparative analysis between phacoemulsification systems mean±SD

Parameters	Active fluidics phacoemulsification system (*n*=1000)	Gravity fluidics phacoemulsification system (*n*=1000)	^{a}P
Fracture CDE	1.1±1.2	1.9±2.1	<0.001
Fragment CDE	4.5±3.1	5.3±3.7	<0.001
Total CDE	5.6±3.9	7.2±5.1	<0.001
Aspiration fluid	70±18	84±21	<0.001

CDE: Cumulative dissipated energy. [a]Independent *t* test was preformed to detect statistically significant differences between groups.

Figure 1 shows a scatter plot with a trend line comparing both phacoemulsification systems. The CDE used was compared between phacoemulsification systems and the cataract classification according to the modified LOCS III. Our findings evidenced that harder cataracts required higher amounts of CDE, as the nucleus is harder to emulsify. The trend line evidenced a more efficient use ultrasound and irrigation in the active fluidic system compared to the gravity-based system in all cataract classifications.

Moreover, the rate of complications was 0.2% using the active fluidics system [1 posterior capsule rupture (PCR) and 1 zonular dialysis] and 0.9% using the gravity-based system (3 PCR, 5 zonular dialysis and 1 IOL change).

DISCUSSION

Our study's main findings suggest that under similar conditions active fluidics phacoemulsification systems could improve surgical outcomes in cataract surgeries. Advances in technology and surgical techniques have improved surgical efficiencies by reducing energy dissipated at the incision site,

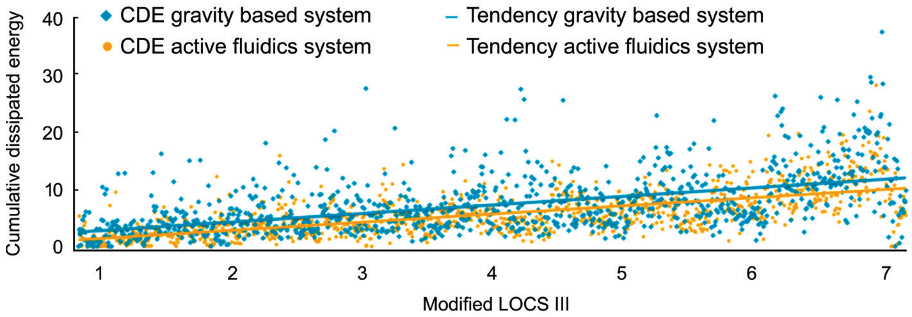

Figure 1 Scatter plot with a trend line comparing CDE and LOCS III classification in both phacoemulsification systems.

fluids circulation through the anterior chamber and surgery time. There was a reduction of 22% in CDE using the active fluidics system when compared to the gravity-based fluidics system ($P<0.001$). These findings are consistent with Chen *et al*'s[6] and Solomon *et al*'s[10] studies, where a reduction of 40% and 38% in CDE between phacoemulsification systems was evidenced, respectively. Additionally, Lawrence *et al*[11] conducted a single surgeon, prospective study which evidenced a reduction of 13.5% in CDE used in phacoemulsification surgeries using the active fluidics dynamic system.

The estimated fluids used in the active-fluidic configuration were significantly lower compared to the gravity-fluidic systems ($P<0.001$). Reducing aspiration fluids during surgery may diminish heat production in the wound, minimizing unwanted corneal stromal changes, wound leaks and shifts in astigmatism[6]. Additionally, maintaining a safe and stable anterior chamber by controlling fluctuations in IOP may reduce instability or collapse, minimizing the risk of trauma to the cornea, the iris, or the lens capsule[7]. Transient increase in IOP is expected during surgery, hence, improving surgical efficiencies may help reduce unwanted damage to ocular structures[8]. A reduction of 16% of fluids used was evidenced using the active fluidics system when compared to the gravity fluidics system. Likewise, Gonzalez-Salinas *et al*[12] evidenced a decrease of 9.28% in aspiration fluids used between phacoemulsification systems by a single surgeon.

Hayashi *et al*[13] identified more complicated cataracts and significant infusion volumes as substantial risk factors for endothelial cell loss. Additionally, Pirazolli *et al*[14] evidenced that the phaco-chop technique requires lower CDE and aspiration fluids to break down a cataract; therefore, it may reduce endothelial cell damage. Consequently, increasing the safety of phacoemulsification surgeries by reducing CDE and aspiration fluids, may improve surgical results and patients postoperative visual acuities[6,15].

Adequate cataract classification should contribute to more predictable and effective cataract surgeries, as dense cataracts require more energy to emulsify[15-16]. Although, the relationship between phacoemulsification energy expenditure and cataract classification may vary between surgeons, technique and equipment used[15,17]. While the active fluidics dynamic phacoemulsification system demonstrated better surgical efficiencies than the gravity-based fluidics system, both systems' rate of complications is low. Different studies have shown no statistically significant differences between the intraoperative complication rate of phacoemulsification systems, as both types of equipment deliver a relatively safe surgical procedure, varying between patients and surgeon[6,11].

This study compared cataract surgeries performed with two phacoemulsification systems under similar conditions which may contribute to better understanding of phacoemulsification surgical parameters. A particular strength of this study is the large number of cases included, performing surgeries using similar ultrasound settings, and surgical techniques with the same phacoemulsification tip and sleeve. These findings were consistent suggesting that the results may be broadly applicable. Nonetheless, this study has some limitations. To identify better surgical results between phacoemulsification system, a prospective study is required to compare postoperative visual acuities, postoperative changes in central corneal thickness and endothelial cell density. These findings are needed to understand further the clinical relevance for preforming cataract surgeries using an active fluidics phacoemulsification system.

In conclusion, surgeries performed under similar conditions (same surgeon, phaco tip and sleeve) with the active fluidics dynamic system required significantly lower CDE and aspiration fluids than the gravity fluidics system. Cataract blindness has a significant impact on the socio-economic development of individuals and societies[18]; therefore, better surgical outcomes are sought to improve postoperative results.

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