Graefe's Archive for Clinical and Experimental Ophthalmology
https://doi.org/10.1007/s00417-026-07209-0

CATARACT

Anterior chamber stability during phacoemulsification: comparing different phacoemulsification systems

Tommaso Rossi[1] · Giorgio Querzoli[2] · Camilla Pellizzaro Deng[1] · Giulia Rosari Deng[1] · Mariacristina Parravano[1,3] · Luca Placentino[1] · Roberto Dell'Omo[4] · David H. Steel[5] · Mario R. Romano[6]

Received: 19 September 2025 / Revised: 3 February 2026 / Accepted: 15 March 2026

Abstract

Purpose To compare in vitro performance of phacoemulsification platforms during critical surgical phases including aspiration, occlusion and occlusion break.

Methods Five phacoemulsification platforms (Alcon Centurion, Bausch & Lomb PC Stellaris, BVI Virtuoso, DORC Eva Nexus and Zeiss Quatera) underwent standardized testing including controlled occlusion within a collapsible test chamber. Tests were conducted with 21G tips, infusion pressure presets 30 and 55 mmHg, flow-rate 30 ml/min and vacuum range 200–600 mmHg. Outcome measures included Intraocular Pressure (IOP) at rest, during aspiration, occlusion and standardized occlusion break as well as chamber volume loss and time to regain 90% of IOP after/during occlusion break.

Results All devices kept target IOP at rest. During aspiration, IOP changed significantly ($p<0.01$): Stellaris showed the greatest IOP reduction, Quatera had small decrease, Virtuoso maintained preset, Centurion and Eva Nexus slightly overcompensated. During occlusion, Eva Nexus and Stellaris PC exceeded the preset 55 mmHg ($p<0.05$) whereas other machines remained on target. Upon occlusion break, volume loss ranged 35-200µL ($p<0.001$) and recovery time to 90% of preset IOP varied between 0.30–2 s ($p<0.001$) with Centurion and Virtuoso outperforming others at 30 mmHg IOP and Centurion, Quatera and Virtuoso at 55 mmHg IOP.

Conclusion Phacoemulsifiers exhibited distinct behaviour under standardized conditions and fluidic settings significantly influenced performance. Surgeon must understand machines' fluidic to master different platforms.

Key messages

What is known

- Anterior Chamber stability is a key feature of safe phacoemulsification surgery
- Post-occlusion surge is a stressful test for phacoemulsification platforms
- A standardized occlusion/post-occlusion break setup allows meaningful comparison
- Lesser volume loss and faster pressure recovery enhance surgical safety

What is new

- Newer "adaptive fluidics" phaco platform show faster recovery and less volume loss
- Intraocular pressure during aspiration significantly varies across platforms
- Time to regain pressure stability after occlusion breaks is as important as time to regain 90% pressure

Keywords Phacoemulsification · Cataract Surgery · Head Loss · Post-occlusion surge · Intraocular pressure · Occlusion Break Surge

✉ Tommaso Rossi
tommaso.rossi@usa.net

[1] IRCCS Fondazione Bietti ONLUS, Via Livenza 3, Roma 00198, Italy

[2] DICAAR Università Degli Studi Di Cagliari, Cagliari, Italy

[3] UniCamillus-Saint Camillus International University of Health Sciences, Rome, Italy

[4] Università Degli Studi del Molise, Campobasso, Italy

[5] Biosciences Institute, Newcastle University, Newcastle Upon Tyne, UK

[6] Department of Biomedical Science, Humanitas University, Milan, Italy

Published online: 25 March 2026

Introduction

Cataract surgery is the most prevalent surgery worldwide, exceeding 30 million procedures per year [1] and Phaco-Emulsification (PE) remains the elective surgical technique [2].

The invariance of Anterior Chamber (AC) pressure and volume during PE, referred to as "AC stability" is a fundamental safety and efficacy requisite as AC shallowing may prompt a cascade of dangerous events compromising the surgical result [3]. Therefore, all leading PE machines, implement strategies to minimize intraoperative pressure and volume fluctuations. The aim of the present study is to use a well-known and previously standardized "in vitro" surgical setting, to characterize the behaviour of the different devices and strategies during an occlusion event.

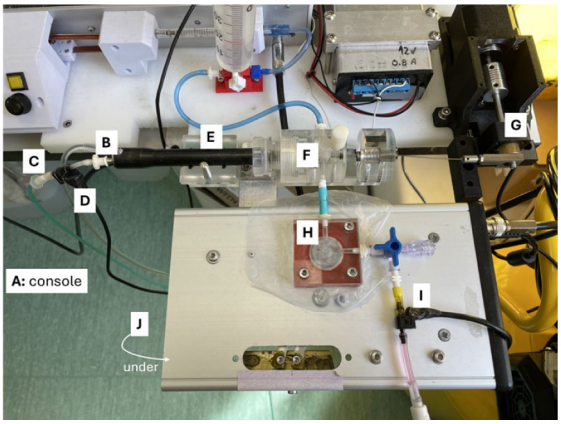
Aspirating lens fragments through small bore tips (21G, 22G), within the minute volume of the anterior chamber, implies high negative pressure and exposes to the risk of sudden AC shallowing. The so-called "post-occlusion aspiration surge" (POAS) [4] is the abrupt and undue vacuum peak, occurring after resolution of aspiration line clogging by lens solid fragments [5]. In fact, when crystalline lens pieces obstruct the PE handpiece tip halting flow, aspiration vacuum rise to the preset maximum value and suddenly "empties" the anterior chamber, as soon as the occlusion resolves and fragments get aspirated. All PE consoles feature strategies aimed at minimizing such an occurrence by reducing tubing compliance, increasing infusion flow and/or pressure or allowing aspiration venting [5].

In *vitro* objective measure of a PE console reaction to post-occlusion aspiration surge proved equally difficult and necessary to develop effective countermeasures [6] and test machine performance. Among the few in vitro settings designed to this specific purpose [7], the one developed by J. and S. Zacharias [8] offers the advantage of a collapsible chamber with volume and compliance comparable to those of the human eye and creates repeatable occlusion-disocclusion cycles, allowing real time recording of volume and pressure.

The purpose of the present paper is to use an expeerimental surgical set-up to compare in vitro the behaviour of different PE platform undergoing POAS cycles under standardized conditions.

Materials and methods

We used the experimental set up described by Zacharias [8] and sketched in Fig. 1, to reproduce standardized PE tip occlusion and disocclusion cycles through a motorized plunger (Fig. 1G) that obstructs the phaco handpiece tip



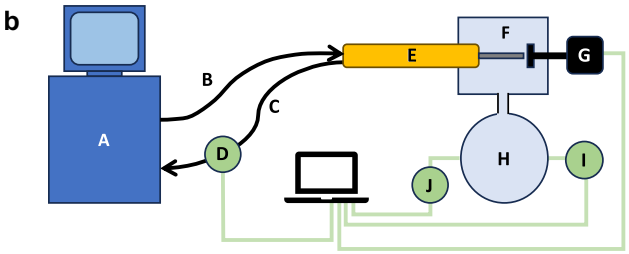


Fig. 1 Picture (**a**) and schematic drawing (**b**) of the experimental set-up used to test phaco tip occlusion under standardized conditions. A PE console, B irrigation line, C aspiration line, D aspiration pressure probe, E Phaco handpiece, F Plexiglas chamber, G servo-controlled occluding device, H compliant chamber, I, IOP probe, J volume sensor. F and H together reproduce the volume and compliance of the anterior chamber

within a mock anterior chamber (Fig. 1F+H) whose compliance can be calibrated to optimally simulate the pressure–volume relation of the human eye [9]. The dimension of the chamber is 200 µL at its maximum expansion and is described in detail elsewhere [7]. The setting includes pressure (Fig. 1J) and volume (Fig. 1I) probes connected to the mock AC, and a pressure probe (Fig. 1D; brand, type, city) to the PE handpiece aspiration line. Simultaneous and continuous recording of volume and pressures on a personal computer allowed data analysis.

Tested PE consoles included: Centurion (Alcon, Fort Worth, TX, USA), Stellaris PC (Bausch & Lomb, Leven, Canada), Virtuoso (BVI Medical, Waltham, MA, USA), DORC Eva Nexus (DORC, Zuidland, The Netherlands), Quatera (Carl Zeiss Meditec, Germany) and all handpieces were mounted with a 21G tip. Console aspiration and irrigation preset values were set as follows: irrigation preset at 30 and 55 mmHg, aspiration vacuum at 200, 300, 400, 500, and 600 mmHg. Flowrate was 30 ml/min for PE consoles installing volumetric pumps (peristaltic, diaphragm and similar) or allowing flow control. All surgical platforms were setup and equipped with proprietary set of tubing. Priming and tuning were also performed and passed according to manufacturers' instructions before any testing was performed.

Since surgical platforms significantly differ in terms of hardware solutions, some of the principal technical solutions related to aspiration and infusion systems implemented on tested machines have been summarized in Table 1.

For each PE console, 10 tests were performed both at 30 and 55 mmHg preset pressure. Each test consisted in 5 occlusions for each aspiration vacuum setting. Each run of the experimental procedure was preceded by the calibration of volume and impendence of the collapsible chamber as described by Zacharias et al. [8].

The occlusion-disocclusion cycle yielded time histories of AC volume and pressure (Fig. 2 exemplifies one such typical graph) and summarized for analysis and comparison in main outcome measures including: the pressure within the model AC during aspiration and occlusion in steady conditions; the maximum AC volume loss occurred during occlusion and the surge recovery time, defined as the time needed to restore 90% of IOP at aspiration steady state. (green arrow in Fig. 2) and the time needed to restore a stable IOP remaining within 10% of the pressure at aspiration steady state (yellow arrow in Fig. 2). Pressure stability after occlusion break in one adjunctive metric that we introduced to track the behaviour of newer adaptive fluidic machines that react to occlusion break surge and sometimes "overshoot" pressure to minimize time to restore a safe IOP.

Statistical analysis used repeated measures ANOVA for continuous variables with post-hoc Bonferroni correction and significance was set at $p<0.05$; JASP (ver. 19.3 Leuven, The Netherlands) was used for statistical analysis and separate analyses were done for each condition.

Table 1 Pump type and infusion systems main features of tested machines. Note that all platforms used volumetric pumps with the only exception of B&L Stellaris PC

	Pump Type	Infusion
Alcon Centurion	Peristaltic pump 7 rollers	compressed BSS bag, no dead space
DORC Eva Nexus	Diaphragm pump	2 pressurized cassette chambers
Zeiss Quatera	Membrane pump 4 chambers	Pressurized cassette chamber
B&L Stellaris PC	Venturi Effect Pump	Pressurized infusion bottle
BVI Virtuoso	Peristaltic and Venturi pump in series	Separate I/A pressurized chambers

Results

Pressure control under static and dynamic conditions

Accuracy of intraocular pressure control at rest, during aspiration and when the phaco tip was occluded, is reported in Figs. 3 and 4 for preset values of 30 mmHg and 55 mmHg, respectively.

All platforms showed accurate IOP control at rest (Figs. 3a and 4a).

During aspiration (Figs. 3b and 4b) and occlusion (Figs. 3c and 4c), IOP showed significant difference across platforms ($p<0.01$ for both): at 30 mmHg preset pressure the

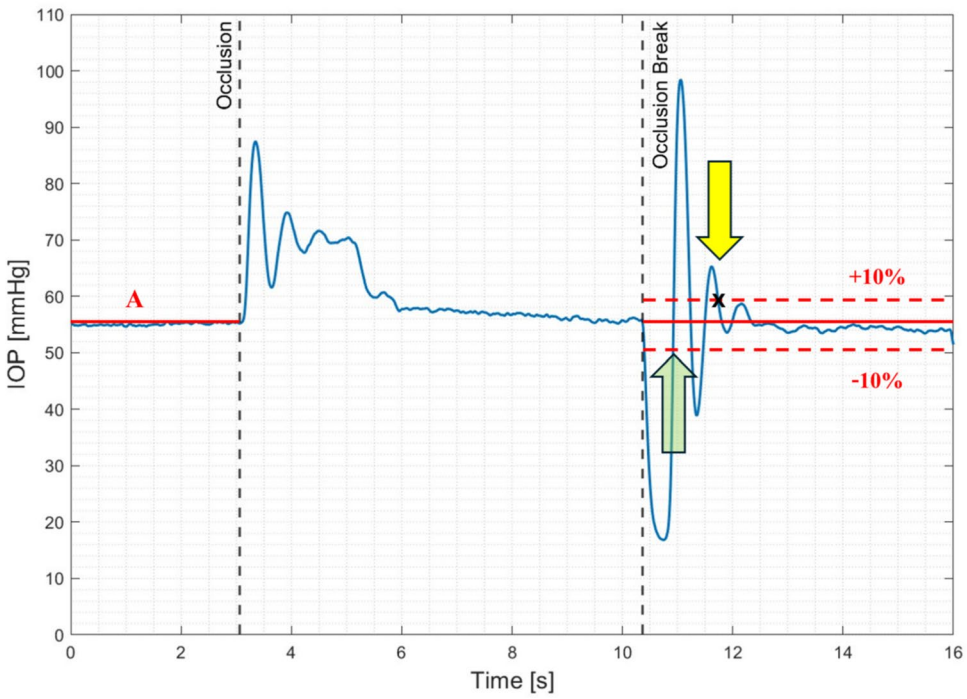


Fig. 2 Pressure graph as a function of time showing one single typical occlusion event. Time to recover IOP stability was measured as the time elapsed from occlusion break (green arrow) to steadily regain IOP within ± 10% of pressure at aspiration (yellow arrow) without IOP oscillation outside 10% tolerance (horizontal dashed red lines represent ± 10% of pressure at steady aspiration)

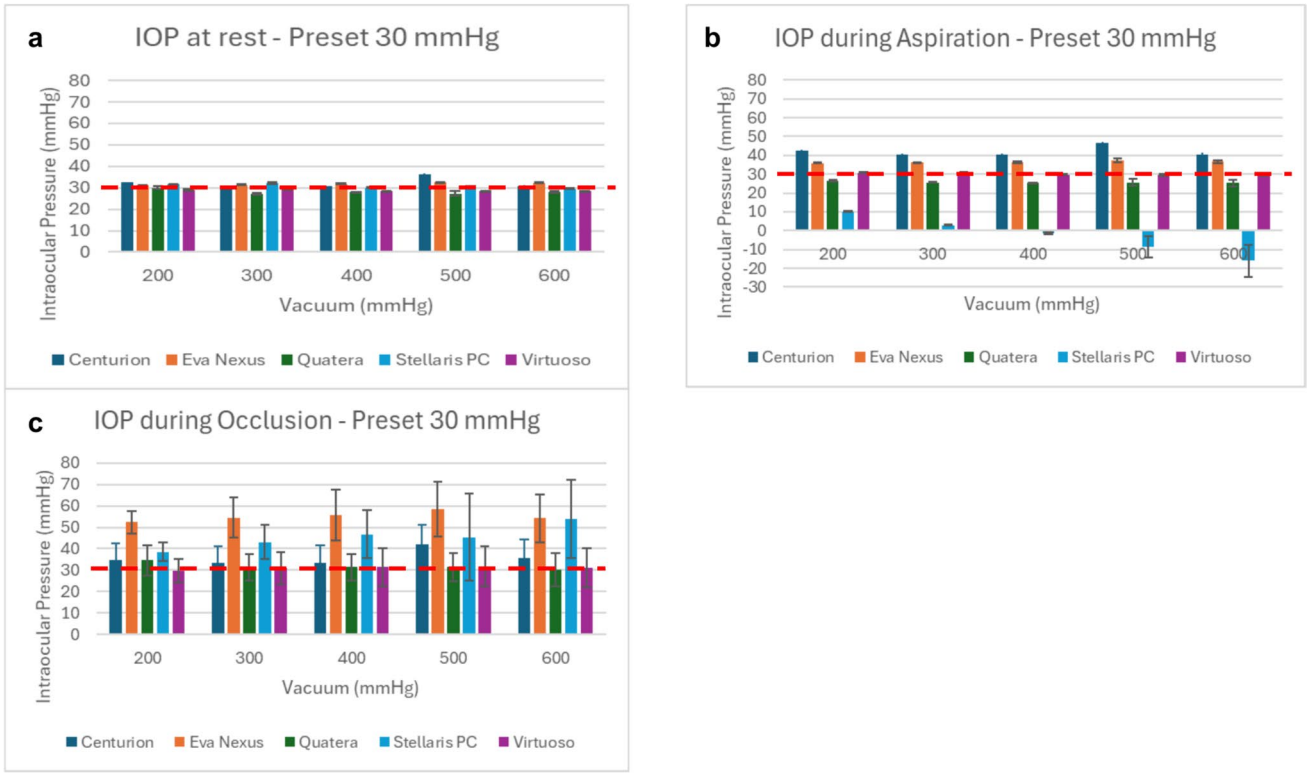


Fig. 3 Bar graph of pressure (in mmHg) within eye model test chamber **a**) at rest, **b**) during aspiration and **c**) during occlusion. IOP preset at 30 mmHg (dashed red line). Bar groups represent different vacuum settings (200–600 mmHg)

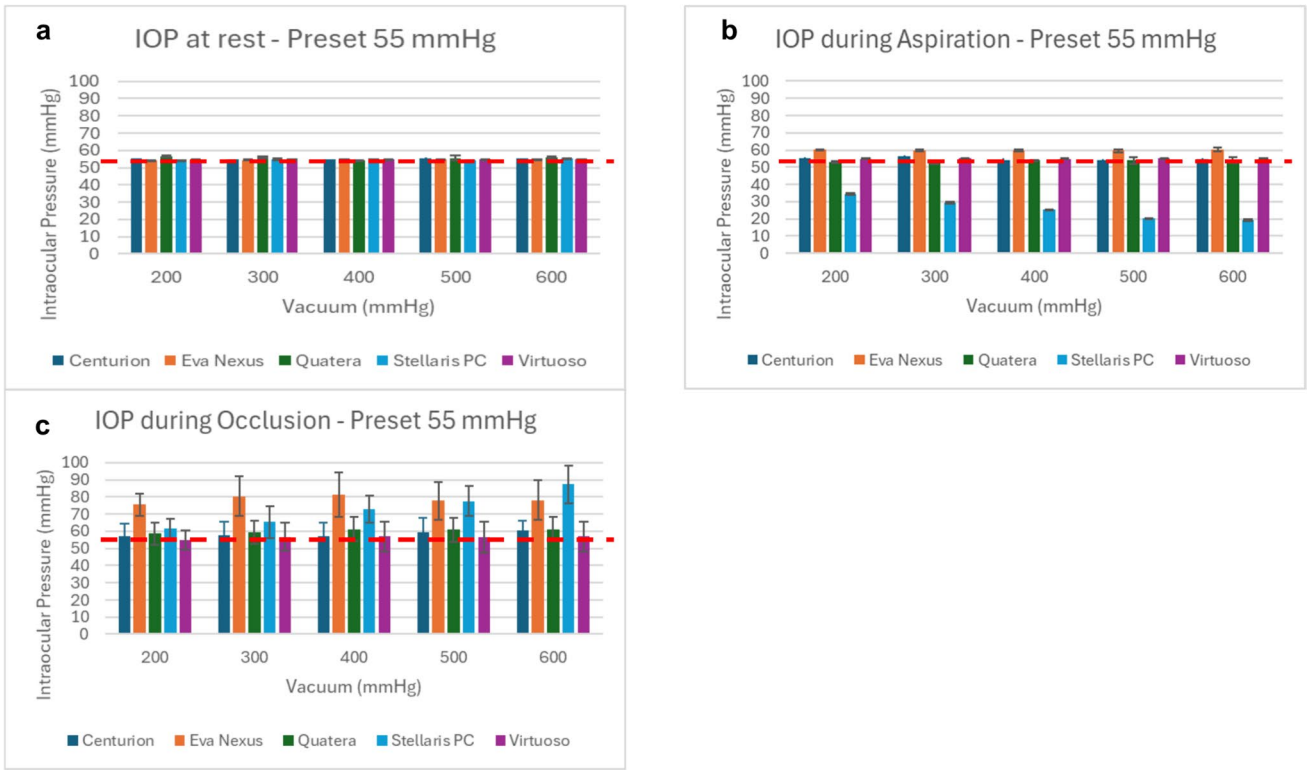


Fig. 4 Bar graph of pressure (in mmHg) within eye model test chamberAC **a**) at rest, **b**) during aspiration and **c**) during occlusion. and IOP preset at 55 mmHg preset (dashed red line). Bar groups represent different vacuum settings (200–600 mmHg)

Stellaris PC showed the highest IOP reduction as aspiration pressure rose while Centurion and Eva Nexus showed over-correction. At 55 mmHg preset, Stellaris PC showed the largest IOP decrease while other platforms remained within 5 mmHg range of the desired pressure.

During occlusion (Figs. 3c and 4c) Eva Nexus and Stellaris PC significantly exceeded pressure preset at 30 and 55 mmHg ($p<0.05$), while the other platforms adhere more strictly to the preset IOP.

Post-occlusion aspiration surge compensation

The loss of volume in the model eye AC, occurring at phaco tip occlusion resolution, is reported in Fig. 5, respectively at 30 (Fig. 5a) and 55 mmHg (Fig. 5b) preset IOP.

There was a significant difference among platforms in volume loss, ($p<0.01$ in both cases; Fig. 5a and b, respectively). Centurion and Virtuoso exhibited the lowest volume decrease at 30 mmHg, while Stellaris PC and Quatera the highest. Increasing the IOP preset at 55 mmHg, the performances were more comparable. Virtuoso showed the lowest volume drop at all vacuum settings, with Quatera and Centurion very close up to 300 mmHg aspiration (Fig. 5b).

The surge recovery time is reported in Fig. 6 and it also showed significant differences between platforms ($p<0.01$). At 30 mmHg preset IOP, the Centurion recovered faster than other machines, up to 300 mmHg aspiration vacuum ($p<0.05$), while over 300 mmHg vacuum Centurion, Quatera and Virtuoso reacted similarly. At 55 mmHg preset IOP performances levelled, with Quatera, Centurion and Virtuoso maintaining a similar and slightly shorter recovery time regardless of aspiration pressure, all recovering in less than 1 s.

A summary of aspiration IOP, volume loss and recovery time at 600 mmHg vacuum is also reported in Table 2.

The time needed to reach stability after POAS is shown in Fig. 7 and showed significant difference among different machines both at 30 mmHg and 55 mmHg ($p<0.05$).

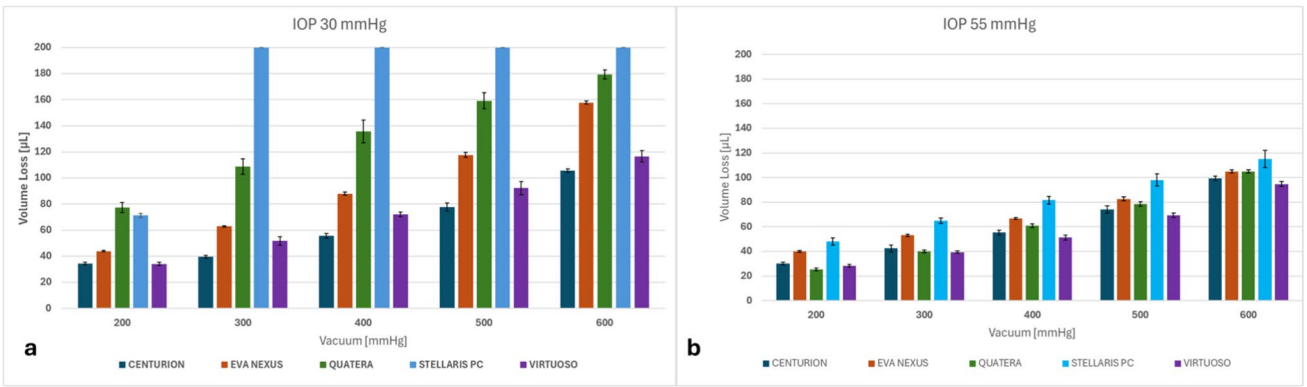


Fig. 5 Bar graph of aqueous volume loss (in microliters) within test chamber after occlusion breaks. Preset intraocular pressure is set at a) 30 mmHg and b) 55 mmHg. Bar groups represent different vacuum settings (200–600 mmHg)

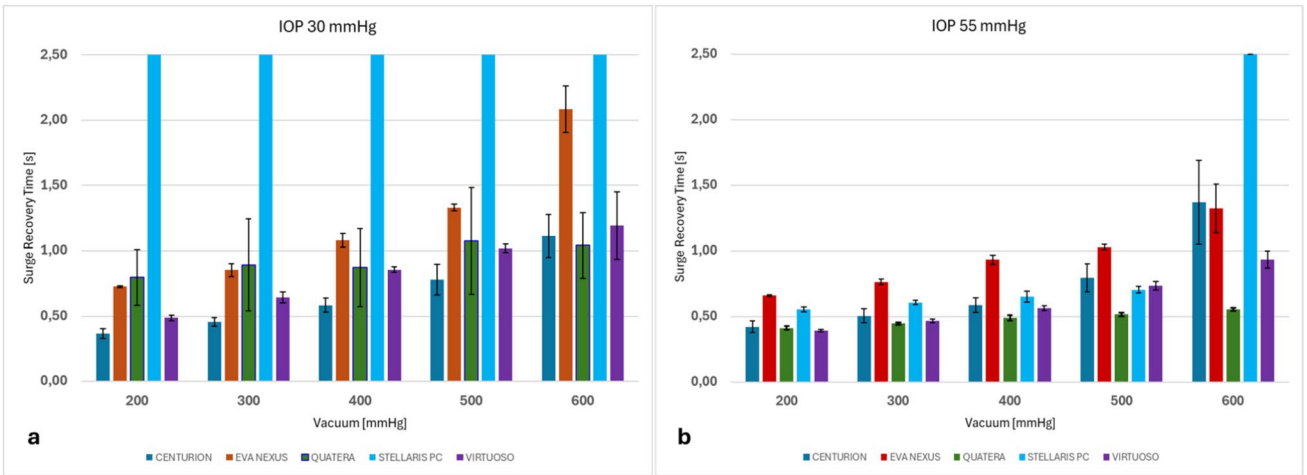


Fig. 6 Bar graph of post-occlusion surge recovery time (in seconds): a) 30 mmHg, and b) 55 mmHg IOP preset. Bar groups represent different vacuum settings (200–600 mmHg). Bars reaching 2.5 s mean the surgical console exceeded 2.5 s to recover volume loss

Table 2 Comparison table of IOP, volume loss and post-occlusion surge recovery time at maximum (600 mmHg) vacuum

	IOP (mmHg) while aspirating @ 600 mmHg		Volume Loss (µL) @ 600 mmHg Vacuum		Recovery Time (s) @ 600 mmHg Vacuum	
IOP Preset	30 mmHg	55 mmHg	30 mmHg	55 mmHg	30 mmHg	55 mmHg
Centurion	40.58±0.71	54.55±0.49	105.53±1.41	99.32±2.01	1.29±0.11	1.59±0.39
Eva Nexus	36.58±0.97	60.42±0.79	157.78±1.19	104.92±1.20	3.71±0.32	2.22±0.33
Quatera	25.23±1.78	54.20±1.81	179.34±3.54	105.10±1.56	2.04±0.44	1.88±0.59
Stellaris PC	−16.0±8.45	19.07±0.50	>200	114.96±6.93	>4.0	>4.0
Virtuoso	29.38±0.28	54.83±0.25	116.58±4.23	94.72±2.07	1.22±0.05	0.96±0.04

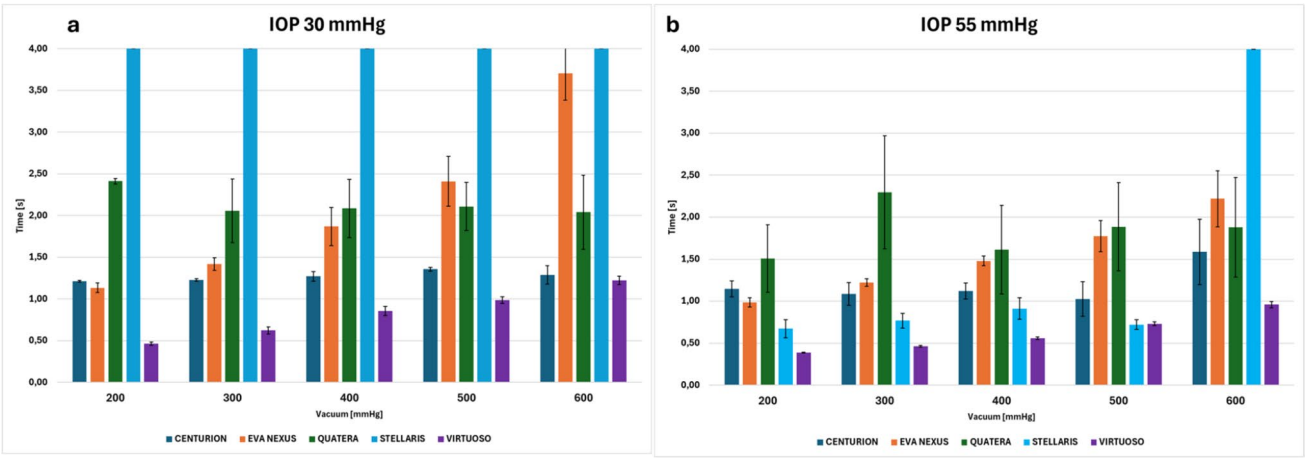


Fig. 7 Bar graph representing the time (in seconds) needed to reach IOP stability after Post-Occlusion Aspiration Surge at a) 30 mmHg preset pressure and b) 55 mmHg aspiration pressure. Bar groups represent different vacuum settings (200–600 mmHg)

Figures 8 and 9 report a single occlusion-disocclusion cycle of each tested machine, at 30 mmHg preset pressure and 55 mmHg, respectively, recorded at 400 mmHg aspiration vacuum.

Discussion

Shallowing of the AC after occlusion break is a dangerous occurrence, potentially leading to severe complications such as posterior capsule rupture, vitreous prolapse, endothelial cell loss and corneal decompensation [10].

All phacoemulsification platforms implement varying "mechanical" stratagems intended to reduce AC pressure and volume variation, including a narrow lumen and increased tubing stiffness to minimize compliance, smaller side ports venting shunts in the phaco needle to prevent complete occlusion, filters in the aspiration line to prevent clogging from lens material and pressure sensors within the handpiece [11].

Phaco machines infusion fluidics have evolved from purely "gravity driven" where the sheer bottle height determined infusion pressure, through "forced infusion" where bottle height remained stable and pressure within a rigid bottle changed through forced air pressure, to "adaptive" or "active" fluidics systems [12–14]. Active systems usually feature multiple chambers equipped with pressure and/or flow transducers that regulate infusion according to sophisticated algorithms "sensing" occlusion and reacting to it [15]. All tested machines belong to the latter generation, featuring varying sophisticated IOP control strategies.

We used a bench setup configuration that has been previously described into details and used on several occasions when introducing novel systems and/or comparing existing platforms [16] and offers the advantage of a collapsible test chamber with adjustable compliance that can be calibrated to match that of the human AC [9]. While in vitro studies necessarily represent a proxy of the surgical setting, they nonetheless possess the advantage of repeatability and a pragmatic measure of simulated surgical event variables.

We compared 5 widely used PE platforms simulating critical tasks related to surgical manoeuvres including aspiration, tip occlusion and post-occlusion break surge, and detected significant differences in terms of fluidic behaviour.

At rest, all platforms precisely kept IOP at the desired value (Figs. 1a and 2a) but behaved differently during the aspiration (Figs. 1b and 2b). A target pressure of 30 mmHg proved to be challenging to maintain as vacuum rose

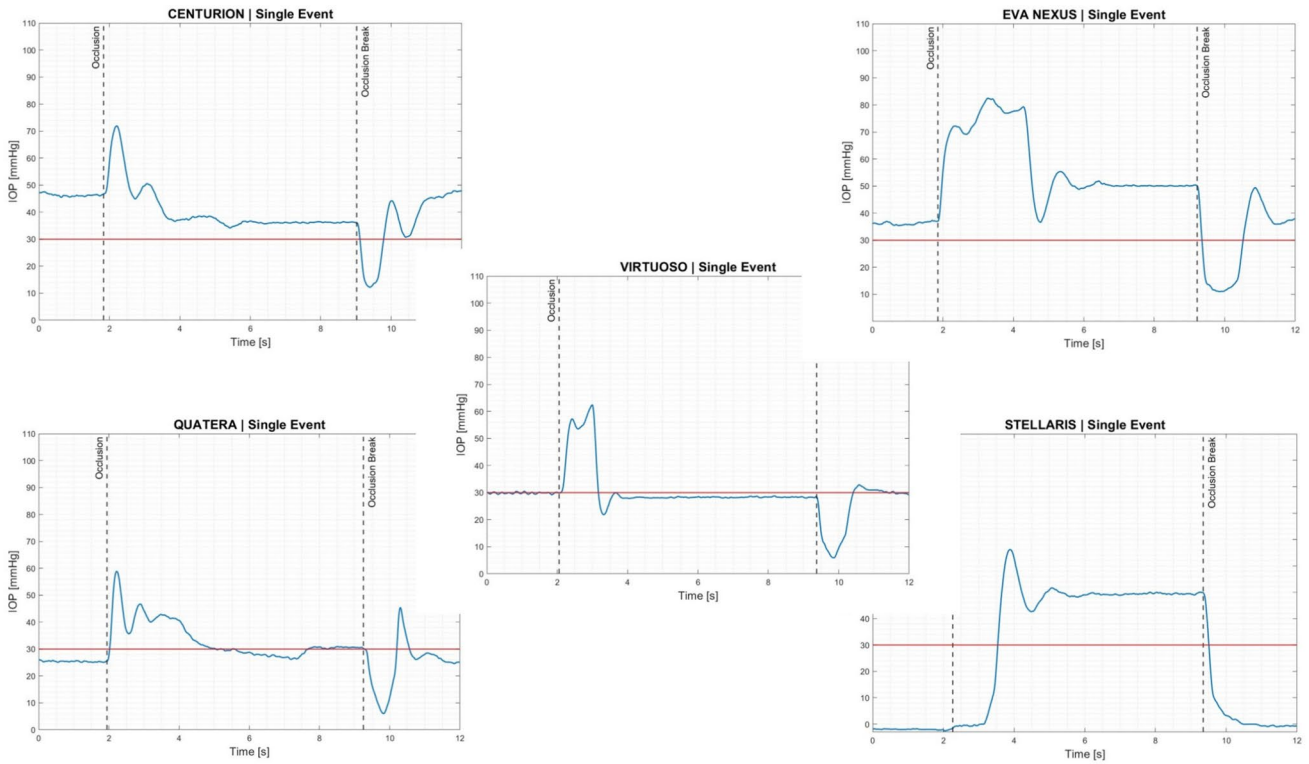


Fig. 8 Pressure (mmHg) in the test chamber as a function of time (s): Example of Occlusion-disocclusion cycle graph at 30 mmHg preset IOP for each tested console

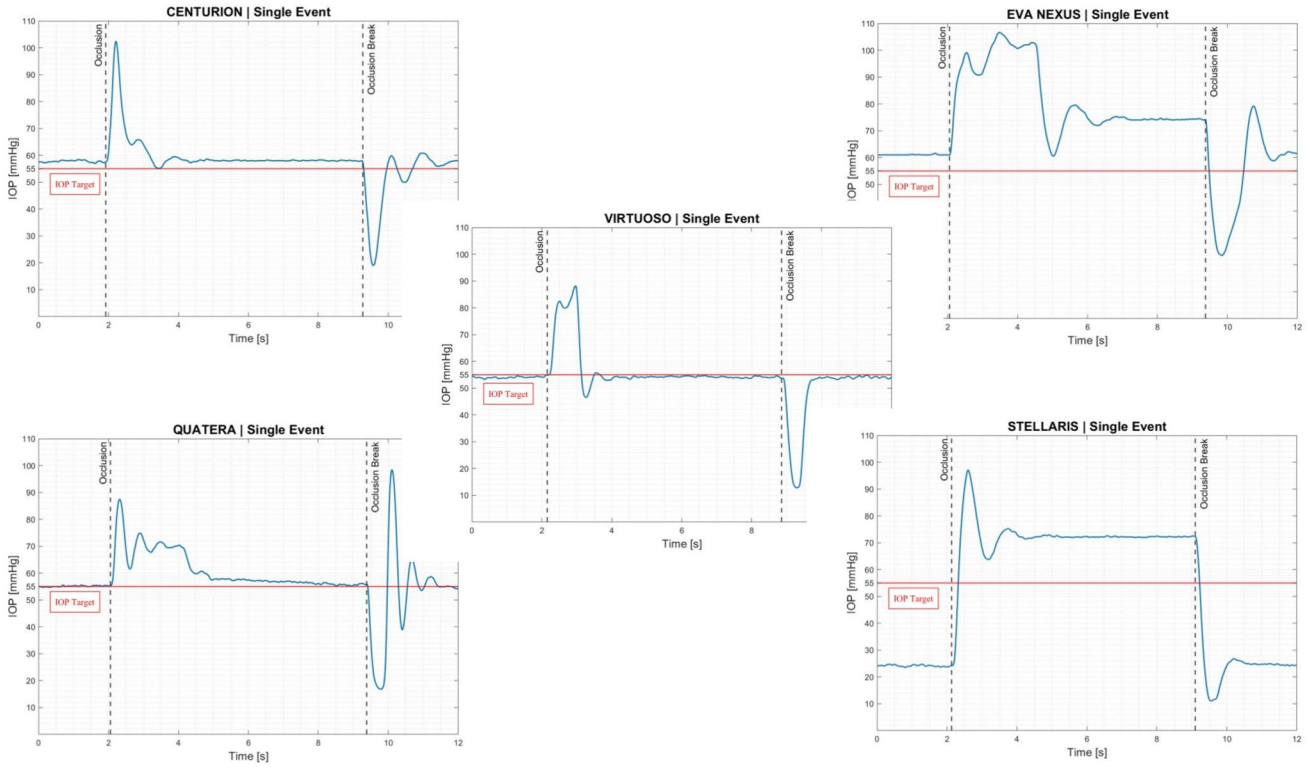


Fig. 9 Pressure (mmHg) in the test chamber as a function of time (s): example of Occlusion-disocclusion cycle graph at 55 mmHg preset IOP for each tested console

(Fig. 1b): Quatera showed a slight IOP decrease, the Stellaris PC did not compensate for the head loss and showed a marked reduction, while Virtuoso remained very close to target and Eva Nexus and Centurion slightly overcompensated. At 55 mmHg preset value, the Stellaris PC still reduced AC pressure (Fig. 2b) while other machines remained closer to the desired value.

Different strategies became apparent when the phaco tip was occluded: IOP increased over target values for the Eva Nexus and Stellaris PC, while Centurion, Quatera and Virtuoso aligned to the requested pressure (Figs. 1c and 2c). The reason for pressure behaviour during aspiration is the result of the different countermeasures adopted to compensate for the pressure drop due to flow induced energy dissipation occurring at aspiration onset. The increase of pressure during occlusion, on the other hand, which could be initially ascribed to the fluid inertia, when persisting, may possibly represent a tentative anticipation of excessive subsequent hypotony at occlusion break. This seems to be the case for Eva nexus and Stellaris PC.

Pressure behaviour during the occlusion-disocclusion cycle proved very consistent and the single event example curves reported in Figs. 8 and 9 for the 2 infusion IOP levels, well highlights the different behaviour of the tested machines.

Before occlusion (Figs. 8 and 9, on the left of the first vertical red dashed line) Centurion and Eva Nexus slightly overcompensated pressure drop, while Quatera and Virtuoso remained more accurately on the target IOP whereas Stellaris PC set at lower values than the preset. During occlusion (Fig. 8 and 9, in between the 2 vertical red dashed lines) a passive infusion system would exactly reach the pressure determined by the bottle height/pressure, while the initial IOP spike relates to abrupt flow cessation. The Quatera and Virtuoso kept the preset pressure, while other active or adaptive fluidics of the Centurion, Eva Nexus and Stellaris PC set at variably higher values, as a strategy to prevent excessive pressure drop at occlusion break.

When occlusion was broken under experimental conditions, (Figs. 8 and 9, right to the second vertical red dashed line), the tested platforms responded differently, helping shed some light on compensation strategies. Not surprisingly, the lowest preset IOP value of 30 mmHg proved more challenging, with 3 out of 5 platforms losing more than 100 µL at 500 mmHg vacuum (Figs. 3a and 8). The amount of AC volume drop levelled off more at 55 mmHg preset IOP, although differences remained statistically significant, and 500 mmHg vacuum resulted in 60–80 µL loss for most platforms (Figs. 3b and 9).

Caution is mandatory when extrapolating experimental data to surgical behaviour during surgery and it should also be stressed that the arbitrary standardized setpoint values we chose for our tests, may not represent the ideal functioning interval for some tested platforms that may perform better under different conditions.

Having said that, [17], the measured volume drop appeared surgically significant, given the average phakic AC volume is about 200 ± 100 µL is, and surgeons should thoroughly know their own platform and carefully choose preset vacuum and IOP, to minimize dangerous AC shallowing.

The surge recovery time also showed interesting differences among platforms; at 30 mmHg preset IOP 3 out of 5 platforms needed about 1 s to restore pressure at 500 mmHg vacuum (Fig. 4a) while at 55 mmHg compensation occurred much sooner (Fig. 4b).

Time to IOP stability (Fig. 7) was introduced to account for the IOP fluctuations shown in Figs. 8 and 9 after occlusion break and most likely related to different compensation strategies deployed by different consoles that temporarily "overshoot" preset IOP to stabilize at a slightly later time. The Virtuoso took a significantly shorter time to reach and maintain IOP within 10% of the steady aspiration state at all vacuum levels and test IOP values, being emulated by Stellaris only at 500 mmHg vacuum.

The surgical significance of the arbitrary 10% cut-off on pressure oscillation and this particular metric itself, remain uncertain although a stable AC pressure is certainly one of the main requisites for a safe surgery.

It should be noted that most available reports on time needed to restore IOP, chose 90% of IOP at occlusion break as the startpoint [5, 15, 16], while we elected to use 90% of the pressure at aspiration steady state as the IOP the machine is actually maintaining during regular use, as consoles not actively compensating aspiration related head loss, may never reach such value.

Understandingly, pressure setpoint proved a key element in that all tested platforms performed better at 55 mmHg of infusion pressure, maintaining closer IOP values during aspiration (Figs. 3 and 4), losing less AC volume after occlusion break (Fig. 5), and recovering faster from it (Fig. 6). Nonetheless, a lower preset IOP around 30 mmHg is highly desirable being much closer to physiologic intraocular pressure levels.

Previous studies using form Fanney and Coll [18] used a modified version of Zacharias' set-up and compared to platforms on 3 IOP levels on two of the same systems we tested, yielded similar results, suggesting data repeatability and consistency.

Aravena et al. [19] repeated measures simulating both phakic and aphakic AC volume, a piece of information we deemed redundant because of the small volume difference, while they did not comment on time necessary to restore volume and pressures at occlusion and during aspiration.

In summary, we compared 5 of the most widely used PE platform in the market while performing in vitro testing simulating routine surgery and found significant differences under experimental conditions simulating aspiration, occlusion and occlusion break. It should be stressed that those platforms differ significantly in terms of construction details, and all deploy proprietary solutions that render each machine unique. As IOP pressure and volume changes during PE is crucial, the data provided during the present tests, though obtained in vitro, can be a valuable information to the surgeon.

Additionally, it should also be noted that cataract surgery can be performed using a variety of surgical techniques including "divide and conquer", "stop and chop", "full phaco chop", "lollipopping", a combination of all the above and many others [20–22], and each technique mandates a different use of the handpiece and fluidics [23] that make the testing of surgical-like settings even more difficult.

Reported data may provide the surgeon with useful information and may represent a valuable support to characterize the performance differences under standardized conditions.

Pitfalls of the present study include the in vitro setting that, if on one side offers the advantage of standardization, on the other suffers the limits of an artefactual *scenario*. More importantly, different machines may work at their best efficiency at settings different from the ones we chose although we spanned a variety of typical IOP, vacuum and flow settings.

Acknowledgements The Authors would like to thank the "Fondazione Roma" and the Italian Ministry of Health for support.

Funding No funding was received for this research.

Declarations

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Financial disclosure Tommaso Rossi is a paid consultant for Beaver Visitec International, all other authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

Competing interest Tommaso Rossi is a paid consultant of BVI medical.

References

1. Cicinelli MV, Buchan JC, Nicholson M, Varadaraj V, Khanna RC (2023) Cataracts. Lancet 401(10374):377–389. https://doi.org/10.1016/S0140-6736(22)01839-6
2. Rossi T, Romano MR, Iannetta D, Romano V, Gualdi L, D'Agostino I, Ripandelli G (2021) Cataract surgery practice patterns worldwide: a survey. BMJ Open Ophthalmol 6(1):e000464. https://doi.org/10.1136/bmjophth-2020-000464
3. Suzuki H, Igarashi T, Takahashi H (2023) Effect of a new phacoemulsification and aspiration handpiece on anterior chamber stability. J Cataract Refract Surg 49(1):91–96. https://doi.org/10.1097/j.jcrs.0000000000001071
4. Georgescu D, Payne M, Olson RJ (2007) Objective measurement of postocclusion surge during phacoemulsification in human eye-bank eyes. Am J Ophthalmol 143(3):437–440. https://doi.org/10.1016/j.ajo.2006.11.017
5. Ricks RG, Cardenas IA, Ungricht EL, Olson RJ, Pettey JH (2023) Effect of modified peristaltic phacoemulsification device on efficiency and post-occlusion pressure surge. Clin Ophthalmol 17:2341–2347. https://doi.org/10.2147/OPTH.S416604
6. Han YK, Miller KM (2009) Comparison of vacuum rise time, vacuum limit accuracy, and occlusion break surge of 3 new phacoemulsification systems. J Cataract Refract Surg 35(8):1424–1429. https://doi.org/10.1016/j.jcrs.2009.03.041
7. Wilbrandt HR, Wilbrandt TH (1993) Evaluation of intraocular pressure fluctuations with differing phacoemulsification approaches. J Cataract Refract Surg 19(2):223–231. https://doi.org/10.1016/s0886-3350(13)80946-7
8. Zacharias J, Zacharias S (2005) Volume-based characterization of postocclusion surge. J Cataract Refract Surg 31(10):1976–1982. https://doi.org/10.1016/j.jcrs.2005.03.061
9. Dyk DW, Miller KM (2018) Mechanical model of human eye compliance for volumetric occlusion break surge measurements. J Cataract Refract Surg 44(2):231. https://doi.org/10.1016/j.jcrs.2017.10.052
10. Sallam MA, Zaky KA (2025) Effect of anterior chamber depth on corneal endothelium following phacoemulsification among patients with different axial lengths. Int Ophthalmol 45(1):45. https://doi.org/10.1007/s10792-025-03415-7
11. Scarfone HA, Rodriguez EC, Rufiner MG, Riera JJ, Fanego SE, Charles M, Albano R (2024) Vitreous-lens interface changes after cataract surgery using active fluidics and active sentry with high and low infusion pressure settings. J Cataract Refract Surg 50(4):333–338. https://doi.org/10.1097/j.jcrs.0000000000001359
12. Chang JS, Ng JC, Chan VK, Law AK (2016) Cataract surgery with a new fluidics control phacoemulsification system in nanophthalmic eyes. Case Rep Ophthalmol 7:218–226
13. Jensen JD, Boulter T, Lambert NG, Zaugg B, Stagg BC, Pettey JH, Olson RJ (2016) Intraocular pressure study using monitored forced-infusion system phacoemulsification technology. J Cataract Refract Surg 42:768–771

14. Rauen MP, Joiner H, Kohler RA, O'Connor S (2024) Phacoemulsification using an active fluidics system at physiologic vs high intraocular pressure: impact on anterior and posterior segment physiology. J Cataract Refract Surg 50(8):822–827. https://doi.org/10.1097/j.jcrs.0000000000001457
15. Luo Y, Li H, Chen W, Gao Y, Ma T, Ye Z, Li Z (2022) A prospective randomized clinical trial of active-fluidics versus gravity-fluidics system in phacoemulsification for age-related cataract (AGSPC). Ann Med 54(1):1977–1987. https://doi.org/10.1080/07853890.2022.2098375
16. Miller KM, Dyk DW, Yalamanchili S (2021) Experimental study of occlusion break surge volume in 3 different phacoemulsification systems. J Cataract Refract Surg 47:1466–1472
17. Shajari M, Herrmann K, Bühren J, Vunnava P, Vounotrypidis E, Müller M, Al-Khateeb G, Kohnen T (2019) Anterior chamber angle, volume, and depth in a normative cohort-a retrospective cross-sectional study. Curr Eye Res 44(6):632–637. https://doi.org/10.1080/02713683.2019.1576205
18. Fanney D, Layser GS, K AR, Kohlhammer S, Kübler C, Seibel BS (2023) Experimental study comparing 2 different phacoemulsification systems with intraocular pressure control during steady-state flow and occlusion break surge events. J Cataract Refract Surg 49(9):976–981. https://doi.org/10.1097/j.jcrs.0000000000001242
19. Aravena C, Dyk DW, Thorne A, Fanney D, Miller KM (2018) Aqueous volume loss associated with occlusion break surge in phacoemulsifiers from 4 different manufacturers. J Cataract Refract Surg 44:884–888
20. Mtanes K, Mimouni M, Sommer AC, Blumenthal EZ (2022) Stop & drop"- a modified "stop & chop" phacoemulsification technique for cataract surgery. Eur J Ophthalmol 32(5):3110–3112. https://doi.org/10.1177/11206721221087557
21. Park J, Yum HR, Kim MS, Harrison AR, Kim EC (2013) Comparison of phaco-chop, divide-and-conquer, and stop-and-chop phaco techniques in microincision coaxial cataract surgery. J Cataract Refract Surg 39(10):1463–1469. https://doi.org/10.1016/j.jcrs.2013.04.033
22. Sato T (2023) Efficacy and safety of the eight-chop technique in phacoemulsification for patients with cataract. J Cataract Refract Surg 49(5):479–484. https://doi.org/10.1097/j.jcrs.0000000000001141
23. Davison JA (2008) Cumulative tip travel and implied followability of longitudinal and torsional phacoemulsification. J Cataract Refract Surg 34(6):986–990. https://doi.org/10.1016/j.jcrs.2008.02.029