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# Comparison of 12-Month Outcomes of Kahook Dual Blade Excisional Goniotomy Performed by Attending versus Resident Surgeons

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## Abstract

**Objective** Kahook Dual Blade goniotomy (KDB) has proven effective in lowering intraocular pressure (IOP) and reducing the medication burden in patients with glaucoma. This study compares outcomes up to 12 months postoperatively after KDB combined with phacoemulsification (phaco-KDB) between an ophthalmology attending and residents.

**Methods** A retrospective analysis was performed on 160 eyes of 113 patients who received a phaco-KDB performed by either an ophthalmology attending or a resident under direct guidance of the attending. Data for each patient was collected preoperatively and at 1 day, 1 week, 1 month, 3 months, 6 months, and 12 months postoperatively. The primary outcome measure was surgical success, defined as 20% IOP reduction or at least 1 medication reduction at 12 months. The secondary outcome measures included mean IOP and medication reduction at each postoperative time point, adverse events, operating time, and survival time, defined as time to failure to meet the criteria for surgical success or requiring a secondary IOP-lowering procedure.

**Results** Preoperative mean IOP was comparable between the two groups ($p = 0.585$), while baseline medications were higher in the attending group ($p = 0.040$). Rate of successful outcomes was similar in both groups at 12 months (73.3% attending vs. 87.5% residents, $p = 0.708$). Mean IOP reduction (1.7 vs. 4.3%, $p = 0.278$) and medication reduction (0.7 vs. 0.6, $p = 0.537$) also did not differ at 12 months. Presence of adverse events was similar between the groups (21.6 vs. 27.3%, $p = 0.938$). The survival time was significantly longer in the attending group ($356.3 \pm 20.2$ days vs. $247.1 \pm 26.8$ days, $p = 0.003$). Resident cases took ~10 minutes longer compared with attending cases ($p < 0.001$).

**Conclusion** IOP lowering outcomes and rate of adverse events of KDB were similar whether the primary surgeon was an attending or a resident surgeon. The survival time was significantly longer in the attending group, but overall success rate was 77.5% for both groups. This suggests phaco-KDB is an effective procedure that can be safely performed by a trainee under direct supervision of an experienced surgeon.

**Keywords**
- glaucoma
- goniotomy
- Kahook Dual Blade
- KDB
- attending
- resident
- outcomes

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Glaucoma is an age-related pathology that comprises much of the blindness around the world. With projections of increasing prevalence of glaucoma, becoming competent in effective and safe surgical management of glaucoma will continue to be a critical component of surgical training.[1] In addition, preliminary data suggests that surgical intervention may be more effective in lowering intraocular pressure (IOP) as compared with medications and address issues of adherence.[2–4] Therefore, ensuring proper surgical training of IOP-lowering procedures, such as microinvasive glaucoma surgery (MIGS), among residents is important. MIGS denotes a group of minimally invasive ab-interno procedures that have shown promise in the reduction in IOP and medication burden in patients with glaucoma while also significantly decreasing the risk of complications, such as hypotony.[5–7]

Goniotomy performed with the Kahook Dual Blade ([KDB] New World Medical, Rancho Cucamonga, CA) is a type of Schlemm's canal MIGS procedure that has shown success in lowering IOP and reducing the medication burden in adult glaucoma patients as both a stand-alone procedure (KDB)[8,9] and combined with phacoemulsification (phaco-KDB).[5,7,10] The design of the parallel blade with a ramp allows a precise excision of the diseased trabecular meshwork en bloc to allow the aqueous humor to directly drain through the Schlemm's canal into the collector channels.[11] In addition to an effective IOP-lowering capacity, phaco-KDB has shown to be a safe procedure with limited vision-threatening complications.[5,7,9,10] Intraoperative or postoperative anterior chamber blood reflux is common and expected as with any Schlemm's canal bypassing procedures,[12,13] but this generally resolves in the first postoperative week without additional intervention.[10,14]

As the surgical treatment of glaucoma continues to increase, the demand for well-trained ophthalmic surgeons who are capable of performing glaucoma procedures will continue to grow. As such, increasing numbers of comprehensive ophthalmologists are beginning to incorporate MIGS into their practice,[15] as well as the potential for a stronger emphasis to be placed on incorporating MIGS into the training curriculum for ophthalmology residency programs. Arguments against MIGS-related training for residents include the complexity required for MIGS and the distractions from teaching basic glaucoma surgical fundamentals, such as filtering and shunt procedures.[16] However, rates of these procedures being performed across the United States are decreasing as MIGS are becoming increasingly utilized due to their efficacy and safety profile, especially early on in the disease process.[17] Data from research studies suggest that resident-performed procedures are generally safe and effective, but there is a lack of published literature on outcomes of MIGS procedures performed by residents.[18,19] The aim of this study was to compare outcomes of phaco-KDB performed by an ophthalmology attending and residents as the primary surgeon up to 12 months postoperatively.

## Methods

### Data Collection

A retrospective analysis was performed on 160 eyes in 113 patients who received a phaco-KDB between February 2017 and June 2019 after receiving approval from the Institutional Review Board (IRB) at the University of Missouri, Columbia. Consecutive patients who received phaco-KDB with minimum 6 months postoperative follow-up were included. The indications for surgery were visually significant cataract with the need for IOP reduction based on their disease severity and progression and/or the desire to reduce the medication burden. The choice of the primary surgeon was based on the attending's discretion, which included the fellow eye status, surgical risks and comorbidities, and patient preference. Eyes that received any other IOP-affecting combined procedures, such as endocyclophotocoagulation, were excluded. Surgical failure was defined as a failure to meet the success criteria at any given postoperative time point or need for a secondary IOP-lowering procedure in the 12-month follow-up period. All residents were inexperienced with angle-surgery at the beginning of their rotation, and each resident performed an average of 20 to 25 cases at the completion of their 4-month glaucoma rotation.

The IRB at the University of Missouri granted a waiver of informed consent due to the retrospective nature of this study. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

### Surgical Procedure

All patients were operated on by either a glaucoma fellowship-trained ophthalmologist (JA) or one of six rotating senior (postgraduate year 4 [PGY-4]) ophthalmology residents under direct supervision of the aforementioned attending at the University of Missouri, Columbia. All patients received topical anesthesia only. KDB goniotomy was performed prior to phacoemulsification through a 2.4 mm temporal clear corneal incision. Under a direct visualization of the angle using a Swan Jacob-style gonioprism, a strip of nasal trabecular meshwork spanning ~4 clock hours was excised using the KDB.[20] The strip was removed completely with microforceps. A standard phacoemulsification with intraocular lens implantation was performed after KDB goniotomy. Viscoelastic was completely removed from the anterior chamber and the eye was filled with balanced salt solution and intracameral Moxifloxacin to achieve an IOP in the mid-20s to minimize early blood reflux. Patients were started on prednisolone acetate 1% and moxifloxacin 0.5%, each four times daily for the first week of recovery, and prednisolone was tapered over 4 weeks. They were advised to continue all of their preoperative glaucoma medications until target IOP was reached and steroid was discontinued. Additional medication was only added if IOP elevated above the target range at any time point.

### Outcome Measures

The primary outcome measure was phaco-KDB success, defined as 20% IOP reduction or at least 1 medication reduction at each postoperative time point. Secondary outcome measures included the survival time to failure or additional IOP-lowering procedure, any adverse events intraoperatively or postoperatively, and operating time. All IOP assessments were performed by an ophthalmologist or a trained technician using Goldmann applanation tonometry. Patient data was collected on the preoperative visit within 1 month prior to surgery, postoperative day 1, week 1, month 1, month 3, month 6, and month 12. Intraoperative and postoperative adverse events included visually-significant hyphema, defined as grade 2 to 4 layered blood in the anterior chamber with decreased vision from the baseline, among other adverse events commonly reported.[9,10,21] Steroid-related IOP spike was assessed separately and defined as an IOP increase of >25% from baseline while on topical prednisolone with minimum IOP of 28 mm Hg and subsequent reduction >25% after discontinuing the topical prednisolone.[22]

### Data Analysis

Data were analyzed in SPSS version 24.0 (SPSS Inc., Chicago, IL) by author MH. A log rank test was run to determine if there was a difference in the survival distribution for attending versus resident. Two-tailed independent *t*-tests or Mann–Whitney U and chi-squared or Fisher's exact tests were employed to assess baseline characteristics. A logistic regression with fixed patient effect was conducted to assess for associations between surgeon training level and success, achievement of target IOPs, complications, and additional procedures. A generalized linear mixed model was used to determine the relationship between surgeon training level and IOP or medication reduction, to account for the contribution of both eyes in some subjects. The level of significance was taken to be $<0.05$. Values are reported as mean ± standard deviation for normally distributed data and percentages for categorical variables unless otherwise specified.

## Results

### Baseline Demographic and Glaucoma Data

The average age of study patients was 69.0 ± 8.8 years. About 57.5% of the eyes belonged to females. Primary open-angle glaucoma was the most commonly treated ($n = 86$, 54%), and 66% were in the mild-to-moderate category per International Classification of Diseases, 10th revision (ICD-10). Baseline mean IOP for all patients was 17.9 ± 4.8 mm Hg and did not differ between two groups ($p = 0.585$). Baseline medications were significantly higher in the attending cohort compared with the resident cohort (2.1 ± 1.2 vs. 1.6 ± 1.2, $p = 0.04$). There was no significant difference between patient age, gender, ethnicity, glaucoma type, and severity among the residents and attending cohorts ($p > 0.05$). Demographic and glaucoma status data are reported in ►**Table 1**.

### Success

Overall, the 12-month success rate was 77.5%, and the difference between the two groups was not statistically

**Table 1** Baseline demographic and glaucoma status data

| | Total ($n = 160$ eyes) | Attending ($n = 116$ eyes) | Resident ($n = 44$ eyes) | *p*-Value[a] |
|---|---|---|---|---|
| Age (y), mean ± SD | 69.0 ± 8.8 | 68.7 ± 9.0 | 69.6 ± 8.2 | 0.423 |
| Range (y) | 43–90 | 43–90 | 50–85 | |
| Gender, *n* (%) | | | | 0.146 |
| Female | 92 (57.5) | 66 (56.9) | 26 (59.1) | |
| Male | 68 (42.5) | 50 (43.1) | 18 (40.9) | |
| Ethnicity, *n* (%) | | | | 0.671 |
| Caucasian | 124 (77.5) | 89 (76.7) | 35 (79.5) | |
| Other | 36 (22.5) | 27 (23.3) | 9 (20.5) | |
| Glaucoma type, *n* (%) | | | | 0.123 |
| Primary open-angle | 86 (53.8) | 66 (56.9) | 20 (45.5) | |
| Other | 74 (46.3) | 50 (43.1) | 24 (54.5) | |
| Glaucoma severity, *n* (%) | | | | 0.100 |
| Mild | 80 (50.0) | 56 (48.3) | 24 (54.5) | |
| Moderate | 18 (11.3) | 12 (10.3) | 6 (13.6) | |
| Severe | 61 (38.1) | 47 (40.5) | 14 (31.8) | |
| Baseline IOP (mm Hg), mean ± SD | 17.9 ± 4.8 | 17.8 ± 5.1 | 18.2 ± 4.2 | 0.585 |
| Baseline medications, mean ± SD | 2.0 ± 1.2 | 2.1 ± 1.2 | 1.6 ± 1.2 | 0.040 |

Abbreviations: IOP, intraocular pressure; SD, standard deviation.
[a]Calculated using Student's *t*-test, Mann–Whitney *U* test, or Fisher's exact test.

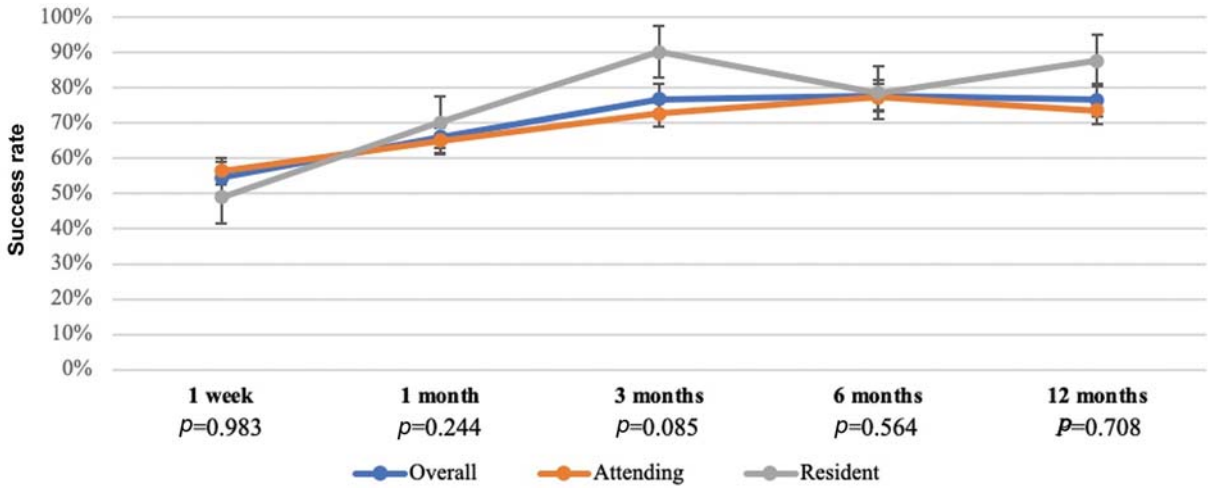


**Fig. 1** Overall, attending, and resident success rates for Kahook Dual Blade combined with phacoemulsification up to 12 months postoperatively.

significant at any postoperative time point (►**Fig. 1**). The success rate, mean IOP, and the number of glaucoma medications at each measured time point are shown in ►**Table 2**.

### Survival Time

Survival time was defined as the postoperative days to the latest time point where the definition of success was not achieved, or until a secondary IOP lowering intervention was needed, if any. The mean survival time for all patients included in the study was 325.7 ± 16.7 days (95% confidence interval [CI] [292.9 days, 358.5 days], ►**Fig. 2**). The mean survival time for eyes in the attending group was 356.3 ± 20.2 days (95% CI [316.7 days, 395.9 days]), compared with 247.1 days ± 26.8 days (95% CI [194.6 days, 299.5 days]) for the resident group (►**Fig. 3**). The difference was statistically significant ($\chi 2 = 8.574$, $p = 0.003$).

### Adverse Events

Adverse events were defined as any intra- or postoperative complication. Need for additional IOP-lowering procedures was not included in the adverse events, but was reported as "failures" and analyzed in ►**Table 3**. In the 12-month follow-up period, 25 (21.6%) attending cases and 12 (27.3%) resident cases had adverse events, and there was no statistical difference ($p = 0.938$). Adverse events reported included grade 2 to 4 hyphema, spill-over vitreous hemorrhage, cystoid macular

**Table 2** Residents versus attending comparison chart of success rates, IOP reduction, and glaucoma medication reduction following phaco-KDB

| | 1 wk | 1 mo | 3 mo | 6 mo | 12 mo |
|---|---|---|---|---|---|
| **Overall** | | | | | |
| Success (%, eyes) | 54.2 (83/153) | 65.9 (87/132) | 76.6 (98/128) | 77.5 (93/120) | 76.3 (58/76) |
| IOP (mean ± SD) | 16.8 ± 6.9 | 15.1 ± 5.3 | 14.8 ± 3.8 | 15.1 ± 3.4 | 15.6 ± 4.6 |
| Medications (mean ± SD) | 1.6 ± 1.4 | 1.7 ± 1.3 | 1.2 ± 1.1 | 1.1 ± 1.2 | 1.3 ± 1.3 |
| Attending | | | | | |
| Success (%, eyes) | 56.3 (63/112) | 64.7 (66/102) | 72.4 (71/98) | 77.1 (64/83) | 73.3 (44/60) |
| IOP (mean ± SD) | 17.2 ± 7.5 | 15.1 ± 5.4 | 15.1 ± 4.1 | 15.4 ± 3.1 | 16.0 ± 5.0 |
| Medications (mean ± SD) | 1.7 ± 1.4 | 1.8 ± 1.3 | 1.2 ± 1.1 | 1.1 ± 1.2 | 1.4 ± 1.2 |
| Resident | | | | | |
| Success (%, eyes) | 48.8 (20/41) | 70.0 (21/30) | 90.0 (27/30) | 78.4 (29/37) | 87.5 (14/16) |
| IOP (mean ± SD) | 15.6 ± 4.7 | 14.8 ± 5.0 | 13.8 ± 2.5 | 14.5 ± 3.8 | 13.9 ± 2.4 |
| Medications (mean ± SD) | 1.5 ± 1.3 | 1.3 ± 1.3 | 0.9 ± 1.0 | 0.9 ± 1.1 | 1.0 ± 1.4 |
| Attending versus resident success rate *p*-values[a] | | | | | |
| Success | 0.983 | 0.244 | 0.085 | 0.564 | 0.708 |

Abbreviations: IOP, intraocular pressure (mm Hg); phaco-KDB, phacoemulsification combined with Kahook Dual Blade goniotomy; SD, standard deviation.
[a]Calculated using Student's *t*-test, Mann–Whitney *U* test, or Fisher's exact test.

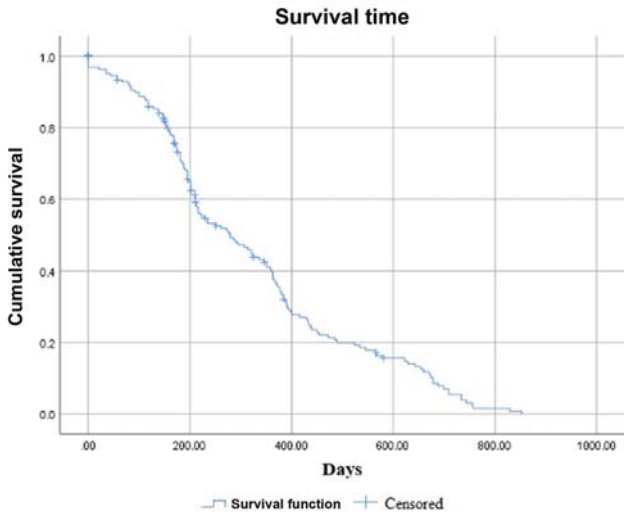


**Fig. 2** Cumulative survival of Kahook Dual Blade combined with phacoemulsification versus days to surgical failure or additional glaucoma surgery graphed as a survival function over time. Log rank test performed for statistical analysis.

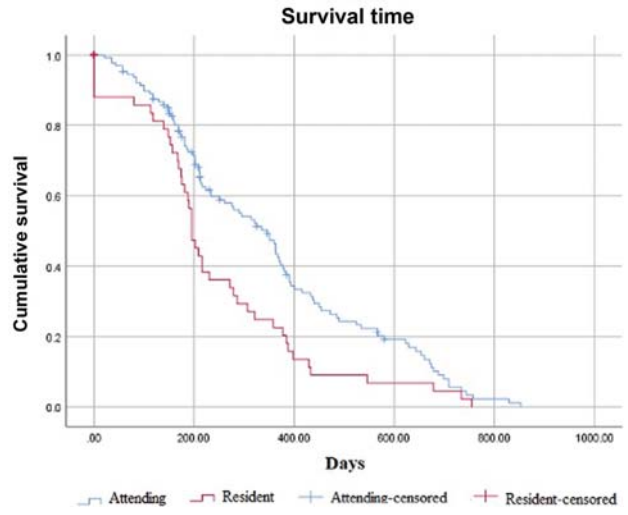


**Fig. 3** Survival function for patients stratified by training of surgeon. Log rank test performed for statistical analysis.

edema, new epiretinal membrane formation, new-onset corneal edema persisting after postoperative week 1, recurrent or new-onset uveitis requiring additional steroid use, and minor iridodialysis/cyclodialysis that did not lead to symptoms or require repair. The rate of steroid response was also similar between both groups (17.2% in attending cohort versus 18.2% in resident cohort, $p = 0.876$). These results are shown in ►**Table 4**.

### Operating Time

The operating time was defined by the time from incision to undraping and included time for phacoemulsification. On average, attending cases were completed in $19.7 \pm 7.2$ minutes as compared with resident cases that averaged $29.7 \pm 10.3$ minutes ($p < 0.001$).

## Discussion

Our study showed that IOP lowering outcomes and adverse events following phaco-KDB were similar between attending and resident cases during the 12-month postoperative period. Our overall 12-month success rate of 77.5%, mean IOP reduction of 2.42 mm Hg, and medication reduction of 0.49 were comparable to other phaco-KDB outcome studies.[5,23] Survival time was significantly longer in the attending cohort as compared with the resident cohort, which may be partially explained by selection bias inherent in nonrandomized studies. Resident cases took ~10 minutes longer in total compared with attending cases. Considering resident cataract surgery often takes longer than that of attending, the actual additional time spent on the KDB goniotomy may be less significant. As shown in previous studies, having experienced surgeons to train residents in a new surgical technique has been beneficial in reducing complications in the operative setting.[14,18] Additionally, residency wet-laboratory workshops, review of surgical videos prior to cases, and close supervision from attending surgeons may also lead to more efficient surgical time management while maintaining low complication rates.[19]

Microhyphema, or suspended red blood cells in the anterior chamber, is an expected observation in the first 2 weeks following phaco-KDB due to blood reflux from Schlemm's canal,[10] and often does not affect the final IOP or best corrected vision.[23] The rate of "visually significant" hyphema defined as grade 2 to 4 hyphema beyond postoperative week 2 of phaco-KDB was low; therefore, we were not able to determine any significant differences between the two cohorts. Future studies determining risk factors for rate of micro- and

**Table 3** Incidence of additional IOP-lowering procedures following phaco-KDB

| Additional procedure | Training level | Day 1 | Week 1 | Month 1 | Month 3 | Month 6 | Month 12 |
|---|---|---|---|---|---|---|---|
| MP-CPC | Resident | | | | 1 (3.3%) | | |
| | Attending | | | | | 3 (3.6%) | 1 (1.7%) |
| LT | Resident | | | | | 1 (2.7%) | |
| | Attending | | | | | 5 (5.0%) | 2 (3.3%) |
| Ahmed valve | Resident | | | | | | |
| | Attending | | | | 1 (1.0%) | | |

**Abbreviations:** IOP, intraocular pressure; LT, laser trabeculoplasty (either selective, argon, or MicroPulse); MP-CPC, MicroPulse cyclophotocoagulation; phaco-KDB, phacoemulsification combined with Kahook Dual Blade goniotomy.

**Table 4** Adverse events in the 12-month follow-up period

| Adverse events (in total), *n* (%) | Attending ($n = 116$) | Resident ($n = 44$) |
|---|---|---|
| Cystoid macular edema | 9 (7.8) | 2 (4.5) |
| Epiretinal membrane | 4 (3.4) | 1 (2.3) |
| Transient corneal edema | 5 (4.3) | 1 (2.3) |
| Recurrent uveitis | 7 (6.0) | 2 (4.5) |
| Hyphema (grade 2–4) | 1 (0.9) | 3 (6.8) |
| Vitreous hemorrhage (spill-over) | 2 (1.7) | 0 (0.0) |
| Iridodialysis or cyclodialysis (minor) | 1 (0.9) | 2 (4.5) |
| Eyes with adverse events, *n* (%)[a] | 25 (21.6) | 12 (27.3) |

[a]Eyes with adverse events are less than adverse events (in total) because some eyes had multiple adverse events.

macrohyphema at all time points following phaco-KDB, including the use of anticoagulants, are currently being conducted by our group. Similarly to microhyphema, a steroid response is common following phaco-KDB[2,24] in patients with glaucoma and juxtacanalicular pathology, and unlikely related to the training level of surgeons.

Previous retrospective reviews comparing residents versus attending's cataract extractions have shown similar outcomes and complication rates overall.[18,25] Similar outcomes were also found when comparing attending and resident-performed tube shunt procedures.[19] Interestingly, Low et al[18] comment that residents who are in their initial 5- to 8-week training period in cataract surgery had higher rates of complications when compared with their supervising attending. Their study included over 2,000 cataract extractions performed by residents. Their rationale behind the increase in resident complications was thought to be due to choosing more advanced cataract cases, increasing resident efficiency in the operating room, and refining surgical techniques.

Similarly, our study result may also be limited by the nature of our nonrandomized retrospective study: more challenging and advanced glaucoma cases may have been performed by the attending instead of residents, skewing better surgical outcomes in resident cases. Thangamathesvaran et al[19] noted the same potential inherent selection bias while evaluating the effect of training level on the outcomes of tube shunt surgeries. An analysis on the effect of training level in neurological surgery also added the possibility that more complex procedures may be referred to teaching hospitals from nonteaching practices.[26] The experience level among training residents may also differ significantly. Expanding the study population to include other residency program's surgical cases in more diverse learning environments may also be beneficial in the future.

The teaching of phaco-KDB and other MIGS in residency programs should continue to be evaluated and utilized in the appropriate patient populations. This study provides supportive evidence that residents are capable of performing phaco-KDB safely and effectively without increasing the risk of intraoperative and postoperative complications when performed under direct supervision of an attending. Additional studies investigating resident versus attending MIGS outcomes will be important in deciding whether to include these surgeries in ophthalmology residency training.

## Conclusion

KDB goniotomy performed by resident surgeons had similar % success, IOP and medication reductions, and complication rates to those performed by the attending surgeon at 12 months. Attending cases had significantly longer survival time and ~10 minutes shorter surgical time compared with resident cases.

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None.

Conflict of Interest
J. A. A. has served as a consultant for New World Medical.

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