A TITLE EXAMPLE

Just an example of a subtitle that can be a bit longer

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1 Introduction

This document aims at demonstrating the capabilities of Quarto's document automation. The document is based on the Setif template.

2 Code blocks using R

2.1 Tables

```
mtcars |>
  knitr::kable()
```

Table 1: mtcars R dataset

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
Mazda RX4	21.0	6	160.0	110	3.90	2.620	16.46	0	1	4	4
Mazda RX4 Wag	21.0	6	160.0	110	3.90	2.875	17.02	0	1	4	4
Datsun 710	22.8	4	108.0	93	3.85	2.320	18.61	1	1	4	1
Hornet 4 Drive	21.4	6	258.0	110	3.08	3.215	19.44	1	0	3	1
Hornet Sportabout	18.7	8	360.0	175	3.15	3.440	17.02	0	0	3	2
Valiant	18.1	6	225.0	105	2.76	3.460	20.22	1	0	3	1
Duster 360	14.3	8	360.0	245	3.21	3.570	15.84	0	0	3	4
Merc 240D	24.4	4	146.7	62	3.69	3.190	20.00	1	0	4	2
Merc 230	22.8	4	140.8	95	3.92	3.150	22.90	1	0	4	2
Merc 280	19.2	6	167.6	123	3.92	3.440	18.30	1	0	4	4
Merc 280C	17.8	6	167.6	123	3.92	3.440	18.90	1	0	4	4
Merc 450SE	16.4	8	275.8	180	3.07	4.070	17.40	0	0	3	3
Merc 450SL	17.3	8	275.8	180	3.07	3.730	17.60	0	0	3	3
Merc 450SLC	15.2	8	275.8	180	3.07	3.780	18.00	0	0	3	3
Cadillac Fleetwood	10.4	8	472.0	205	2.93	5.250	17.98	0	0	3	4
Lincoln Continental	10.4	8	460.0	215	3.00	5.424	17.82	0	0	3	4
Chrysler Imperial	14.7	8	440.0	230	3.23	5.345	17.42	0	0	3	4
Fiat 128	32.4	4	78.7	66	4.08	2.200	19.47	1	1	4	1
Honda Civic	30.4	4	75.7	52	4.93	1.615	18.52	1	1	4	2
Toyota Corolla	33.9	4	71.1	65	4.22	1.835	19.90	1	1	4	1
Toyota Corona	21.5	4	120.1	97	3.70	2.465	20.01	1	0	3	1
Dodge Challenger	15.5	8	318.0	150	2.76	3.520	16.87	0	0	3	2
AMC Javelin	15.2	8	304.0	150	3.15	3.435	17.30	0	0	3	2
Camaro Z28	13.3	8	350.0	245	3.73	3.840	15.41	0	0	3	4
Pontiac Firebird	19.2	8	400.0	175	3.08	3.845	17.05	0	0	3	2
Fiat X1-9	27.3	4	79.0	66	4.08	1.935	18.90	1	1	4	1
Porsche 914-2	26.0	4	120.3	91	4.43	2.140	16.70	0	1	5	2
Lotus Europa	30.4	4	95.1	113	3.77	1.513	16.90	1	1	5	2
Ford Pantera L	15.8	8	351.0	264	4.22	3.170	14.50	0	1	5	4
Ferrari Dino	19.7	6	145.0	175	3.62	2.770	15.50	0	1	5	6
Maserati Bora	15.0	8	301.0	335	3.54	3.570	14.60	0	1	5	8
Volvo 142E	21.4	4	121.0	109	4.11	2.780	18.60	1	1	4	2

TODO: long tables does not repeat header and the bottom is crushed

```
quakes  |>
  knitr::kable()
```

Table 2: dataset JohnsonJohnson

lat	long	depth	mag	stations
−20.42	181.62	562	4.8	41
−20.62	181.03	650	4.2	15
−26.00	184.10	42	5.4	43
−17.97	181.66	626	4.1	19
−20.42	181.96	649	4.0	11
−19.68	184.31	195	4.0	12
−11.70	166.10	82	4.8	43
−28.11	181.93	194	4.4	15
−28.74	181.74	211	4.7	35
−17.47	179.59	622	4.3	19
−21.44	180.69	583	4.4	13
−12.26	167.00	249	4.6	16
−18.54	182.11	554	4.4	19
−21.00	181.66	600	4.4	10
−20.70	169.92	139	6.1	94
−15.94	184.95	306	4.3	11
−13.64	165.96	50	6.0	83
−17.83	181.50	590	4.5	21
−23.50	179.78	570	4.4	13
−22.63	180.31	598	4.4	18
−20.84	181.16	576	4.5	17
−10.98	166.32	211	4.2	12
−23.30	180.16	512	4.4	18
−30.20	182.00	125	4.7	22
−19.66	180.28	431	5.4	57
−17.94	181.49	537	4.0	15
−14.72	167.51	155	4.6	18
−16.46	180.79	498	5.2	79
−20.97	181.47	582	4.5	25
−19.84	182.37	328	4.4	17
−22.58	179.24	553	4.6	21
−16.32	166.74	50	4.7	30
−15.55	185.05	292	4.8	42
−23.55	180.80	349	4.0	10
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

2.2 Raw outputs

```
glm <- glm(mpg ~ disp, data = mtcars)
glm
```

```

Call:  glm(formula = mpg ~ disp, data = mtcars)

Coefficients:
(Intercept)         disp
   29.59985     -0.04122

Degrees of Freedom: 31 Total (i.e. Null);  30 Residual
Null Deviance:      1126
Residual Deviance: 317.2    AIC: 170.2
```

2.3 Plots

```
glm <- lm(mpg ~ disp, data = mtcars)
plot(mpg ~ disp, data = mtcars) # add general linear model dashed line
abline(glm, col = "blue", lty = 2)
```

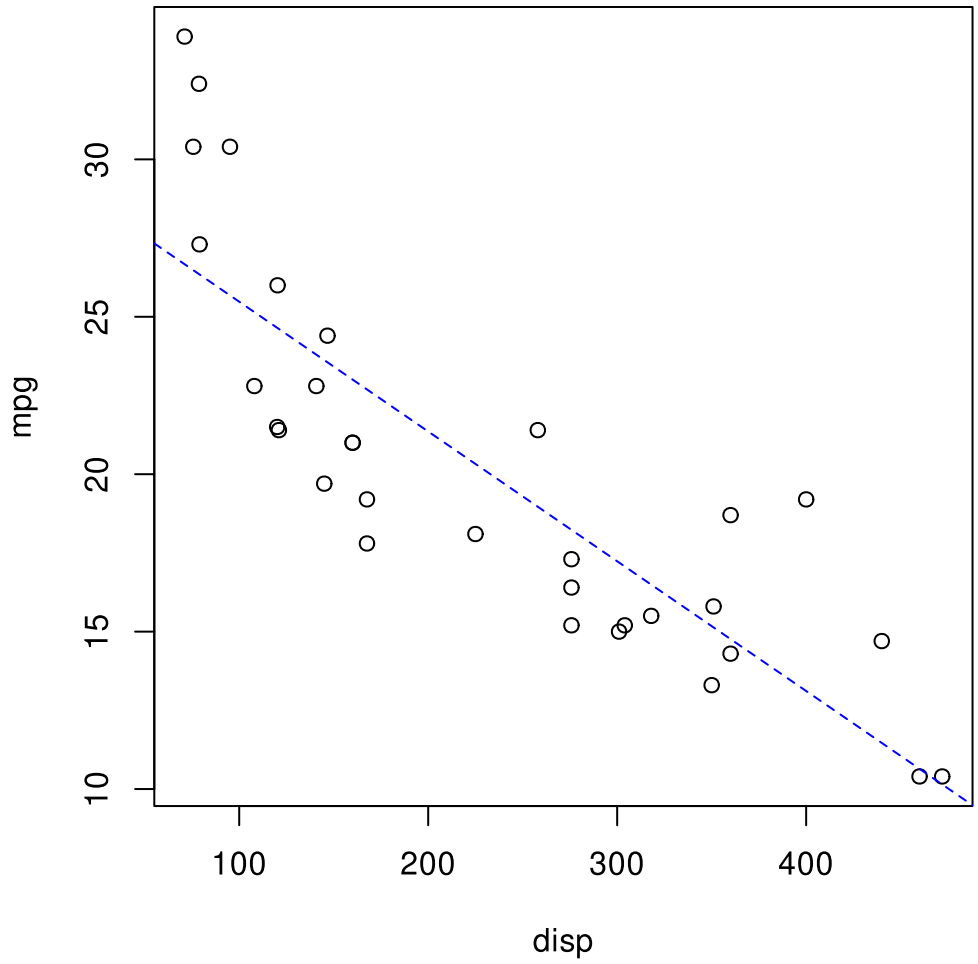

Figure 1: The figure describes the relationship between displacement and miles per gallon based on the mtcars dataset

3 Cross ref and refs

3.1 Cross references

The code block presented in Section 2.1 uses `R` to generate a table. The `mtcars` dataset is shown in Table 1.

4 Inline code blocks for automatic reporting

Here we can present an example of an inline code block. This is very useful for automatic reporting as we can use variables to include them directly in the text. For instance, the mean mpg of cars is shown 20.090625 (i.e. the previous number was generated using the `mean()` function from the `base` package).

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INTRAOPERATIVE AND POSTOPERATIVE COMPLICATIONS IN PHACOVITRECTOMY FOR EPIRETINAL MEMBRANE AND MACULAR HOLE

A Clinical Audit of 1000 Consecutive Eyes

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Purpose: The aim of this study was to report the intraoperative and postoperative complications of phacovitrectomy for epiretinal membrane (ERM) and macular hole (MH).

Methods: This was a retrospective audit of 1,052 phacovitrectomy operations (410 for ERM and 642 for MH) by the same surgical team between 1998 and 2017. Outcome measures included rates of intraoperative anterior segment and posterior segment complications such as posterior capsule rupture and retinal breaks. A subgroup analysis of 189 procedures in which postoperative complications were rigorously recorded was also undertaken.

Results: The rate of posterior capsule rupture was 2.2%, with no difference between ERM and MH (1.7 vs. 2.5%; $P = 0.40$). Iatrogenic retinal tears were more common in MH than in ERM surgery (15.6 vs. 6.8%; $P < 0.001$). The chance of one or more anterior segment or posterior segment intraoperative complications occurring (excluding iatrogenic retinal breaks) was not associated with: indication for surgery, grade of surgeon, gauge of surgery, surgical machine, diabetic status, patient sex, or patient age. Subgroup analysis showed postoperative events as follows: posterior capsular opacification 10.6% (20/189), posterior synechiae 4.2% (8/189), uveitis 2.1% (4/189), angle closure glaucoma 1.6% (3/189), and rhegmatogenous retinal detachment 1.1% (2/189).

Conclusion: Phacovitrectomy seems to be safe in phakic patients with ERM or MH, performed either by fellows or consultants. It avoids the requirement for repeat surgery and is more cost and resource efficient.

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Vitrectomy may be combined with cataract surgery (phacovitrectomy) in the management of phakic eyes with macular hole (MH) or epiretinal membrane (ERM).[1] Even with minimal preexisting cataract, phacovitrectomy may be preferred to vitrectomy alone to preempt the progression of postvitrectomy cataract and provide quicker overall visual recovery from a single procedure.[2]

Although phacovitrectomy is more time and resource efficient than vitrectomy followed by sequential cataract surgery, there have been concerns that it may be associated with a higher risk of intraoperative and perioperative complications.[1] The effect of longer surgical time and the interaction of posterior segment manipulation and tamponade on anterior segment structures are issues that have been previously raised.[1] Specifically, posterior synechiae formation, small myopic refractive shift, and posterior capsule opacification (PCO) have been reported.[3–5] Whether vitreoretinal (VR) surgeons are as adept at anterior segment surgery compared with high-volume cataract surgeons is another potential debate. However, combined surgery negates the requirement for postvitrectomy cataract surgery which has its own challenges, including an increased risk of posterior capsular rupture and zonular dehiscence.[6] There are also economic

considerations, with phacovitrectomy being up to 20% more cost-efficient than 2-step surgery.[7]

Overall, the published evidence to date suggests that phacovitrectomy is safe in the management of MH and ERM.[8] The literature, however, is confined to small uncontrolled studies on phacovitrectomy and to small comparative case series on phacovitrectomy versus sequential cataract surgery.[4,9,10] There are no large, published series on phacovitrectomy outcomes, which would help to inform the discussion and future decision making.

The aim of this study was to report our institution's experience in more than 1,000 consecutive phacovitrectomy operations performed by the same group of VR surgeons (consultants and fellows) for MH and ERM with emphasis on intraoperative complication rates and with a subgroup analysis on postoperative complications.

Methods

This retrospective, consecutive case series was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained by an institutional review board. All VR operations, including phacovitrectomies, performed at our institution since October 1998 under the care of 3 consultant VR surgeons (T.H.W., D.A.H.L., and R.S.W.) have been prospectively recorded on an electronic patient record (EPR) system (Vitreor; AxSys Technologies, Glasgow, United Kingdom). Mandatory data-entry fields for each operation include: laterality of affected eye, indication for surgery, surgical procedure undertaken, and intraoperative complications. The EPR can also record postoperative data including postoperative complications but these data fields are not mandatory.

Main Cohort

An anonymized search was performed for all phacovitrectomy operations undertaken at our institution for MH or ERM between October 1998 and June 2017. The primary outcome was the incidence of intraoperative complications. The rates of specific anterior segment and posterior segment complications were compared by chi-square analysis between: ERMs and MHs; consultants and fellows; 20-G and small-gauge (23-G or 25-G) surgery; and use of the Accurus machine (Alcon Laboratories, Fort Worth, TX) versus the Constellation machine (Alcon Laboratories). Multivariate logistic regression was performed to determine risk factors associated with having one or more anterior segment or posterior segment intraoperative complications, respectively, among the following: indication for surgery (ERM vs. MH), patient age, diabetic status, grade of surgeon (fellow vs. consultant), trocar gauge, and phacovitrectomy machine (Accurus vs. Constellation). For reporting purposes, posterior capsule rupture (PCR) in our study was defined as either 1) a tear of the posterior capsule with or without vitreous loss or 2) vitreous loss with an intact posterior capsule, for example due to zonular rupture, in keeping with the definitions used in large, landmark reports on cataract surgery complications.[11,12] Statistical testing was performed using SPSS version 20 with $P < 0.05$ considered statistically significant.

Postoperative Subgroup

A subgroup of consecutive cases performed by a single consultant (THW) over a 3-year period was identified (the "Post-op" subgroup) where postoperative data including postoperative complications were rigorously recorded. A secondary outcome of the study was to determine for this subgroup the incidence of the following postoperative events: PCO, raised intraocular pressure, uveitis, posterior synechiae (PS), vitreous hemorrhage, retinal detachment, and endophthalmitis.

Surgical Procedure

Cataract surgery was performed by phacoemulsification before vitrectomy as a planned procedure in all cases. Anterior and posterior segment surgeries were performed with the same machine. Before January 2010, the Accurus was used and thereafter the Constellation. Machine settings such as infusion pressure, cut rate, and vacuum varied based on individual surgeon preferences. Capsulorhexis was performed manually in all cases using a needle or forceps.

Results

There were 1,052 phacovitrectomies performed on 991 patients during the study period for either MH (n = 642) or ERM (n = 410). This represented the majority (81%) of all phakic eyes treated for ERM or MH at our institution over the study period and especially in the last 5 years of that period (91%). Demographics

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None of the authors has any financial/conflicting interests to disclose.

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and operative details are outlined in Table 1. Fellows performed more surgery than consultants but the proportion of fellow cases was similar for both MH and ERM (58 vs. 57% respectively). Patients undergoing MH were statistically younger than those undergoing ERM, but this discrepancy did not seem to be clinically relevant (69.0 vs. 70.4 years, $P = 0.007$). Compared with ERM cases, MH cases were more likely to: be female (71 vs. 50%, $P < 0.001$), involve gas tamponade (99 vs. 12%, $P < 0.001$), use 20-G trocars (47 vs. 35%, $P < 0.001$), and use the Accurus machine (39 vs. 29%, $P = 0.001$). The discrepancy in gauge and instrumentation between ERMs and MHs is a reflection of our institution's changing case-mix over time. Proportionately more MH procedures were performed early in the study period when 20-G trocars and the Accurus machine were standard.

Intraoperative complications are shown in Table 2 with comparisons by: surgical indication (ERM vs. hole), grade of surgeon (consultant vs. fellow), gauge of surgery (20-G vs. small-gauge) and machine (Accurus vs. Constellation). The PCR rate was 2.2% overall in the series. The rate of PCR and the rates of other specific anterior segment complications were not statistically different across any of the comparator groups, with the exception of the rate of AC tears, which were higher for fellows (1.6%) than consultants (0.0%, $P < 0.01$). Regarding posterior segment complications, the only statistically relevant difference across groups occurred in the rates of retinal tears, which were more common in MH (vs. ERM), 20-G surgery (vs. small-gauge surgery), and use of the Accurus machine (vs. Constellation). Post hoc testing confirmed that these three factors in addition to diabetes were statistically correlated with retinal tears ($P < 0.001$) on multivariate regression, whereas patient age, sex, and surgeon grade were not significant ($P > 0.05$).

Multivariate logistic regression found the chance of having one or more anterior segment complications during phacovitrectomy was not associated ($P > 0.05$) with any of the following: indication of surgery (ERM vs. MH), grade of surgeon (fellow vs. consultant), gauge of surgery (20-G vs. smaller gauge), machine (Accurus vs. Constellation), diabetic status of patient, patient sex, or patient age. Likewise, the chance of having one or more posterior segment intraoperative complications (excluding iatrogenic retinal tears) was not correlated with any of these aforementioned variables.

There were 189 phacovitrectomy cases in the "Post-op" subgroup. The demographic data were comparable with the wider study, with a mean age of 68 years, a female preponderance (56%), 61% having surgery for MH, 47% using 20-G trocars, and 60% having surgery using the Constellation. The intraoperative complications were also similar to the wider study with a PC rupture rate of 2.1%. Follow-up ranged from 6 weeks to 14 years with a median of 0.47 years. Postoperative events in descending order of frequency were as follows: PCO (10.6%, n = 20); raised intraocular pressure (5.8%, n = 11), posterior synechiae

Table 1. Demographics and Surgical Details of Phacovitrectomy Cases

	ERM	MH	All	*P**
n	410	642	1,052	—
Mean age (years)	70.4	69.0	69.5	0.007†
Sex	49.6% female	71.2% female	62.8% female	<0.001‡
Diabetes	Yes: 63 (15.4%) No: 347 (84.6%)	Yes: 73 (11.4%) No: 569 (88.6%)	Yes: 136 (12.9%) No: 916 (87.1%)	0.06‡
Grade of surgeon	Cons: 176 (42.9%) Fellow: 234 (57.1%)	Cons: 267 (41.6%) Fellow: 375 (58.4%)	Cons: 443 (42.1%) Fellow: 609 (57.9%)	0.67‡
Machine	Accurus: 117 (28.5%) Constell: 293 (71.5%)	Accurus: 247 (38.5%) Constell: 395 (61.5%)	Accurus: 364 (34.6%) Constell: 688 (65.4%)	0.001‡
Gauge of surgery	25-G: 51 (12.4%) 23-G: 217 (52.9%) 20-G: 142 (34.6%)	25-G: 55 (8.6%) 23-G: 285 (44.4%) 20-G: 302 (47.0%)	25-G: 106 (10.1%) 23-G: 502 (47.7%) 20-G: 444 (42.2%)	<0.001‡
Gas tamponade	Yes: 48 (11.7%) SF_6: 31 (7.6%) C_2F_6: 11 (2.7%) C_3F_8: 6 (1.5%) No: 362 (88.3%)	Yes: 637 (99.2%) SF_6: 53 (8.3%) C_2F_6: 205 (31.9%) C_3F_8: 379 (59.0%) No: 5 (0.8%)	Yes: 685 (65.1%) SF_6: 84 (8.0%) C_2F_6: 216 (20.5%) C_3F_8: 385 (36.6%) No: 367 (34.9%)	<0.001‡
Laser and/or cryotherapy	Yes: 116 (28%)	Yes: 209 (33%)	Yes: 325 (31%)	0.145‡

*Epiretinal membrane versus macular hole.
†Student's *t*-test two-tailed.
‡Chi-square test two-tailed.
Cons, consultant; Constell, Constellation machine; G, gauge.

Table 2. Intraoperative Complications in Phacovitrectomy With Breakdown by Surgical Indication, Surgeon Grade, Trocar Gauge, and Machine

Intraoperative Complication	Total (n = 1,052)	ERM (n = 410)	MH (n = 642)	*P**	Fellow (n = 609)	Consult (n = 443)	*P*†	20g (n = 444)	23g and 25g (n = 608)	*P*‡	Accurus (n = 364)	Constell (n = 688)	*P*§
Anterior Segment													
One or more AS complications	46 (4.4%)	16 (3.9%)	30 (4.7%)	0.55	27 (4.4%)	19 (4.3%)	0.91	23 (5.2%)	23 (3.8%)	0.27	19 (5.2%)	27 (3.9%)	0.33
PCR and/or vitreous loss	23 (2.2%)	7 (1.7%)	16 (2.5%)	0.40	10 (1.6%)	13 (2.9%)	0.16	10 (2.3%)	13 (2.1%)	0.90	9 (2.5%)	14 (2.0%)	0.64
AC tear¶	10 (1.0%)	4 (1.0%)	6 (0.9%)	0.94	10 (1.6%)	0 (0.0%)	0.007	4 (0.9%)	6 (1.0%)	0.89	3 (0.8%)	7 (1.0%)	0.76
Iris trauma/ prolapse	6 (0.6%)	2 (0.5%)	4 (0.6%)	0.77	3 (0.5%)	3 (0.7%)	0.70	4 (0.9%)	2 (0.3%)	0.22	3 (0.8%)	3 (0.4%)	0.43
Zonular dialysis	6 (0.6%)	2 (0.5%)	4 (0.6%)	0.77	6 (1.0%)	0 (0.0%)	0.05	3 (0.7%)	3 (0.5%)	0.70	2 (0.5%)	4 (0.6%)	0.95
Lens exchange/ other IOL problems	5 (0.5%)	3 (0.7%)	2 (0.3%)	0.33	1 (0.2%)	4 (0.9%)	0.17	3 (0.7%)	2 (0.3%)	0.42	3 (0.8%)	2 (0.3%)	0.23
Dropped lens	0 (0.0%)	0 (0.0%)	0 (0.0%)	—	0 (0.0%)	0 (0.0%)	—	0 (0.0%)	0 (0.0%)	—	0 (0.0%)	0 (0.0%)	—
Other	0 (0.0%)	0 (0.0%)	0 (0.0%)	—	0 (0.0%)	0 (0.0%)	—	0 (0.0%)	0 (0.0%)	—	0 (0.0%)	0 (0.0%)	—
Posterior segment													
Retinal tears	128 (12.2%)	28 (6.8%)	100 (15.6%)	<0.001	81 (13.3%)	47 (10.6%)	0.19	77 (17.3%)	51 (8.4%)	<0.001	64 (17.6%)	64 (9.3%)	<0.001
Vitreous Hg	2 (0.2%)	1 (0.2%)	1 (0.2%)	0.99	0 (0.0%)	2 (0.5%)	0.18	1 (0.2%)	1 (0.2%)	0.82	0 (0.0%)	2 (0.3%)	0.30
Subretinal Hg	2 (0.2%)	1 (0.2%)	1 (0.2%)	0.99	1 (0.2%)	1 (0.2%)	0.99	1 (0.2%)	1 (0.2%)	0.82	1 (0.3%)	1 (0.1%)	0.65
Choroidal or suprachoroidal Hg	7 (0.7%)	2 (0.5%)	5 (0.8%)	0.71	3 (0.5%)	4 (0.9%)	0.46	2 (0.5%)	5 (0.8%)	0.46	2 (0.5%)	5 (0.7%)	0.74

*Chi-square two-tail tested for epiretinal membrane versus macular hole.
†Chi-square two-tailed test for fellow versus consultant grade surgeon.
‡Chi-square 2-tailed test for 20-gauge surgery versus small-gauge (23- or 25- gauge) surgery.
§Chi-square two-tailed test for Accurus machine versus Constellation machine.
¶Anterior capsule tear refers to either run-out of the anterior capsule during capsulorhexis or tears to a normal capsulorhexis occurring during the remainder of phacoemulsification surgery.
AC, anterior capsule; AS, anterior segment; Constell, constellation; Consult, consultant surgeon; G, gauge; IOL, intraocular lens; Hg, hemorrhage; PC, posterior capsule.

Table 3. Anterior Segment Complications Compared With the Cataract-Only Literature

Intraoperative Complications	This Study (n = 1,052)	RCONOD[11] (n = 180,114)	NCD[15] (n = 55,567)
One or more complications (AS or SCH)	4.9%	4.2%	4.6%
PCR and/or vitreous loss	2.2%	2.0%	1.9%
Other	1.0%	0.7%	1.1%
Iris trauma/prolapse	0.6%	0.5%	0.6%
Zonular dialysis	0.6%	0.5%	0.5%
Epithelial abrasion	0.0%	0.3%	0.2%
Endothelial damage/Descemet's tear	0.0%	0.2%	0.3%
Nuclear/epinuclear fragment into vitreous	0.0%	0.2%	0.2%
Corneal edema	0.0%	0.1%	0.1%
Lens exchange/other IOL problems	0.5%	0.1%	0.1%
Phaco burn/wound problems	0.0%	<0.1%	0.2%
Hyphema	0.0%	<0.1%	<0.1%
Choroidal/suprachoroidal hemorrhage	0.7%	<0.1%	<0.1%

AS, anterior segment; IOL, intraocular lens; NCD, National Cataract Dataset; PC, posterior capsule; RCONOD, Royal College of Ophthalmologist's National Ophthalmology Database; SCH, suprachoroidal hemorrhage.

(4.2%, n = 8), uveitis (2.1%, n = 4), ocular surface disease (2.1%, n = 4), angle closure glaucoma (ACG, 1.6%, n = 3), persistent CMO (1.6%, n = 3), retinal detachment (1.1%, n = 2), early gas dissipation (1.1%, n = 2), vitreous hemorrhage (0.5%, n = 1), toxic anterior segment syndrome (0.5%, n = 1), refractive surprise (0.5%, n = 1), and endophthalmitis (0.0%, n = 0). Of the 8 patients who developed PS, none had intraoperative complications, all had gas tamponade and 6 (75%) occurred with 20-G surgery. Eight percent (6/88) of 20-G cases developed PS versus 2% (2/101) for small-gauge ($P = 0.10$).

Overall, there were 3 cases of ACG in the postoperative subgroup. One case occurred in the early postoperative period, whereas the other 2 presented as delayed events at 6 months and 3 years. All 3 cases involved gas tamponade (2 with C_3F_8 and 1 with C_2F_6) and none were associated with any intraoperative complications. Two ACG cases were successfully treated using peripheral iridotomy and medical therapy, while 1 required glaucoma drainage surgery.

Discussion

We performed a large, retrospective audit on the safety of phacovitrectomy surgery. Anterior segment intraoperative complications in our series were comparable with rates reported in recent cataract-only series. Posterior capsule rupture is widely regarded as an indicator of the quality of cataract surgery and, in our series, measured 2.2%.[11–14] In 2 large, multicentre studies on cataract surgery using EPR data from the United Kingdom, PCR rates were 1.92% (from the National Cataract Dataset) and 1.95% (from the Royal College of Ophthalmologists' National Ophthalmology Database, RCONOD) in 55,567 and 180,114 cataract operations, respectively.[11,12,15] In addition to PCR, the rates of other anterior segment complications in our phacovitrectomy series were similar to results from the aforementioned EPR-based cataract reports, as shown in Table 3.

Suprachoroidal hemorrhage after cataract surgery occurred in 0.05% and 0.07% of cases in the RCONOD[11] and National Cataract Dataset series,[15] respectively. The rate in our phacovitrectomy series was considerably greater at 0.7%. However, allowance must be made for the additional risk with pars plana vitrectomy. We have previously published on suprachoroidal hemorrhage after pars plana vitrectomy alone, with incidences of 1.0 and 0.6% for 20-G and 23-G surgery, respectively.[16] This indicates that compared with sequential surgery, the risk of suprachoroidal hemorrhage in our phacovitrectomy series was acceptable.

Analysis of intraoperative complications (Table 2) revealed that retinal tears were more common with: MH (vs. ERM), 20-G (vs. small-gauge) surgery, and Accurus (vs. Constellation) machinery. The association of retinal tears with MH over ERM has been reported elsewhere[17] and most likely reflects the discrepancy in PVD status between the two conditions, with a greater proportion of MHs requiring PVD induction. The association of tears with larger trocar gauge[16–19] and with lower cut-rate machines[20] is again

consistent with previous reports on vitrectomy-only surgery—and is consistent with the widely acknowledged effect these instrumentation factors have on intraoperative vitreous traction. Because of limitations in our data collection, specific machine settings such as vacuum and cut rates were not faithfully recorded for each case; so, we could not explore the independent contribution of these factors in our study.

Although larger trocar gauge and older, lower cut-rate machinery were correlated with retinal tears, it was interesting that these instrumentation factors were not correlated with an increased risk of one or more (nonretinal tear) posterior segment complications. This may reflect a lack of statistical power in our study, given that hemorrhagic posterior segment complications (e.g., suprachoroidal hemorrhage) occur at such low rates in phacovitrectomy. However, our findings may be considered consistent with a previous report on vitrectomy-only surgery, where no overall statistical difference in suprachoroidal hemorrhage rates was found between 20-G and 23-G surgery.[16]

Regarding postoperative complications, PCO requiring YAG capsulotomy was the most common event with an incidence of 10.6%. This rate compares favorably with previous reports of PCO in vitrectomized eyes where incidence has varied between 10% and 51%.[6,21–26] Vitrectomy before or combined with cataract surgery is a recognized risk of PCO.[25,26] Our relatively low rate may be attributable to our standard IOL, which was a hydrophobic acrylic lens (AcrySof SA60AT; Alcon) known to have a low propensity for PCO after cataract-only surgery.[27] All eyes in our postoperative subgroup were operated by a single surgeon who aimed to leave the posterior capsule intact (surgeon preference). Some surgeons in our unit perform prophylactic posterior capsulotomy with the vitrectomy cutter to prevent PCO.[28]

Our subgroup retinal detachment rate was 1.1%, which is consistent with RCONOD data of 1.0% and 2.4% for PPV in ERM and MH, respectively.[29,30] The incidence of PS formation was 4.2% in our subgroup, which is comparable with a previous report by Oh et al[31] (6.1%) on 23-G phacovitrectomy. Posterior synechiae seems to be less common with small-gauge phacovitrectomy than traditional 20-G surgery, where rates in some series have been as high as 19% to 34%.[32] This trend was evident in our own results; although PS occurred in 6.8% (6/88) of 20-G cases in the postoperative subgroup, it occurred in only 2% (2/101) of small-gauge (23-G and 25-G) cases ($P = 0.10$).

Posterior synechiae formation is very uncommon after routine cataract surgery. Its occurrence after phacovitrectomy may be attributed to the effect of tamponade agents on the iris-capsular-bag diaphragm. All eight cases of PS in our series involved gas tamponade. Gas and oil tamponade have been linked with PS formation after phacovitrectomy in previous reports.[31] A proinflammatory effect from combined surgery may also play a role in PS formation, with prolonged surgical time associated with PS in some series.[31] Two of eight cases of PS in our series occurred in the context of active uveitis.

The incidence of uveitis in our series (2.1%) was higher than one would anticipate after routine cataract surgery, where the incidence from large series has been reported as low as 0.24%.[33] Rates of uveitis after vitrectomy alone for macular disease are not well documented. It was our standard practice to prescribe either dexamethasone 0.1% or prednisolone acetate 1% drops QDS for 4 weeks for combined cases, which was the same protocol we used in cataract-only cases. Our practice in this regard is consistent with a recent survey of VR surgeons, which found that the majority use the same anti-inflammatory protocol for phacovitrectomy as for cataract-only cases, despite these surgeons reporting that phacovitrectomy is more inflammatory than cataract surgery alone.[34] This paradox suggests the need for further research to standardize best practice. Our study lends support to the rationale for increasing the frequency of steroid drops and/or using adjuvant anti-inflammatory drops for combined cases to counteract these inflammatory tendencies.

In 3 cases in our series (1.5%), ACG developed. All 3 cases had uncomplicated surgery with gas tamponade. A similar incidence of ACG (1.82%) was reported by Raj et al[35] in their series of 493 phacovitrectomies, although all their ACG cases occurred with oil rather than gas. After routine cataract surgery, ACG is exceedingly rare. In vitrectomy-only cases, an early intraocular pressure spike with a shallow anterior chamber can occur due to gas overfill, ciliary body rotation, or gas trapped behind the iris in the posterior chamber.[36] However, late ACG is rarely reported in these cases. Our findings suggest that patients counseled for combined surgery should be warned of this additional risk. The fact that 2 of 3 ACG cases presented more than 6 months after phacovitrectomy highlights the importance of advising patients, even those who have had uncomplicated surgery, of the importance of annual intraocular pressure monitoring.

We did not assess refractive outcomes in this study but have previously reported a small myopic shift (approximately −0.3D) in phacovitrectomy for macular disease compared with routine cataract surgery.[37] This is consistent with several other reports.[38,39]

Significantly, we observed the same magnitude myopic shift with sequential cataract surgery after previous vitrectomy as with combined phacovitrectomy,[37] suggesting that factors related to vitrectomy (or a history of vitrectomy) are likely to explain myopic shift rather than factors inherent to combined surgery as such. The size of myopic shift in combined surgery in both our own experience and in much of the literature[37–39] has been small in absolute terms and can be mitigated by optimizing biometric constants.

Aside from MH and ERM, combined phacovitrectomy may be useful in other VR pathologies such as diabetic retinopathy, retinal detachments, or trauma, particularly when there is significant lens opacification obscuring fundal views.[1,40] We did not extract data for these patients because of the varying baseline characteristics and prognostic outcomes of this heterogeneous group. In eyes requiring surgery for diabetic retinopathy, it has been our practice to limit combined surgery to cataracts that impair the operative view because vitrectomy has been shown to induce less cataract in diabetic vitrectomy.[41] In addition, we prefer to avoid prolonging intraocular surgery in diabetic patients in whom retinal surgery is likely to be more complex in the first place.

The main limitation of our study was its retrospective design. The integrity of EPR data entered in the time-pressured clinical environment may be compromised by inaccuracies and omissions. There is also a well-documented tendency for surgeons to underrecord their complications.[42] For these reasons, we chose to compare the complication rates in our series against studies that have faced similar constraints: where data has been extracted retrospectively from EPR platforms.

Our results provide important evidence for the safety profile of phacovitrectomy surgery when undertaken by VR consultants and fellows. Anterior segment intraoperative complications were similar to published rates encountered with cataract surgery alone, whereas posterior segment complications were similar to those encountered with vitrectomy alone. Vitreoretinal surgeons at our institution frequently perform cataract surgery, whereas this may not be the case in all units. This variability could influence the decision on whether to perform combined surgery. The decision should also take account of patient factors, especially age. Patients aged 50 years and younger are less likely to develop postvitrectomy cataract.[43] They are also more likely to have clear lenses and residual accommodative function so that lens extraction is best avoided. An informed discussion on the risks and benefits of combined surgery is essential in all cases, including the risks of refractive errors and postoperative inflammation. In our subgroup analysis, postoperative safety was acceptable, although the rates of uveitis and ACG seemed higher than would be encountered after cataract surgery alone. Further research is required on ways to minimize these events postoperatively. Preemptive anti-inflammatory treatment and regular postoperative monitoring are recommended. As instrumentation improves, these complications are likely to become rarer and this trend was observed in our own series. It is our unit's standard practice to perform phacovitrectomy in most phakic patients with ERM or MH even where cataract is mild. Phacovitrectomy avoids the additive risks associated with repeat surgery and is more time, cost, and resource efficient.[7]

Key words: epiretinal membrane, macular hole, phacovitrectomy, complications, safety, postoperative, intraoperative.

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Visual outcomes and subjective experience after bilateral implantation of a new diffractive trifocal intraocular lens

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PURPOSE: To assess clinical outcomes and subjective experience after bilateral implantation of a diffractive trifocal intraocular lens (IOL).

SETTING: Midland Eye Institute, Solihull, United Kingdom.

DESIGN: Cohort study.

METHODS: Patients had bilateral implantation of Finevision trifocal IOLs. Uncorrected distance visual acuity, corrected distance visual acuity (CDVA), and manifest refraction were measured 2 months postoperatively. Defocus curves were assessed under photopic and mesopic conditions over a range of +1.50 to −4.00 diopters (D) in 0.50 D steps. Contrast sensitivity function was assessed under photopic conditions. Halometry was used to measure the angular size of monocular and binocular photopic scotomas arising from a glare source. Patient satisfaction with uncorrected near vision was assessed using the Near Activity Visual Questionnaire (NAVQ).

RESULTS: The mean monocular CDVA was 0.08 logMAR ± 0.08 (SD) and the mean binocular CDVA, 0.06 ± 0.08 logMAR. Defocus curve testing showed an extended range of clear vision from +1.00 to −2.50 D defocus, with a significant difference in acuity between photopic conditions and mesopic conditions at −1.50 D defocus only. Photopic contrast sensitivity was significantly better binocularly than monocularly at all spatial frequencies. Halometry showed a glare scotoma of a mean size similar to that in previous studies of multifocal and accommodating IOLs; there were no subjective complaints of dysphotopsia. The mean NAVQ Rasch score for satisfaction with near vision was 15.9 ± 10.7 logits.

CONCLUSIONS: The trifocal IOL implanted binocularly produced good distance visual acuity and near and intermediate visual function. Patients were very satisfied with their uncorrected near vision.

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Multifocal intraocular lenses (IOLs) are becoming more widely used as patients increasingly seek spectacle independence after cataract surgery.[1,2] The optical principles of multifocal IOLs include diffractive, zonal refractive, and aspheric designs, and the design may have a significant impact on postoperative visual outcomes. Diffractive IOLs are based on the Huygens-Fresnel principle, in which concentric rings on the optic surface typically generate 2 foci (distance and near), with a proportion of incident light lost at higher orders of diffraction.[3] Numerous studies[4–6] have found that diffractive IOLs can provide good distance and near visual acuity, despite the loss of some energy. However, patients may still be dependent on spectacles for intermediate vision after implantation of bifocal diffractive IOLs.[6–8]

A combination of 2 diffractive profiles can provide 3 foci for an IOL. Gatinel et al.[9] describe a trifocal IOL design featuring a diffractive pattern on the anterior optic surface consisting of alternating diffractive steps of different heights. The 2 specific diffractive patterns result in foci for distance vision, intermediate vision (+1.75 diopter [D] addition [add]), and near vision (+3.50 D add). The Finevision IOL (Physiol) uses this trifocal design; the IOL received Conformité Européenne status in February 2010. It has an apodized

optic with decreasing step height from the center to the periphery, resulting in variable distribution of light energy to far, intermediate, and near vision with changing pupil diameters.[A] The proportion of incident light directed to far vision is greater than for near or intermediate vision at all pupil diameters and rises with pupil size to increase distance-vision dominance.

There are little published data on the in vivo clinical outcomes with trifocal IOL designs. Vokresenskaya et al.[10] describe the initial results of implantation of the MIOL-Record trifocal IOL (Reper NN) in 36 eyes (28 patients). They found the IOL gave good distance, intermediate, and near acuity; however, there were frequent subjective reports of halos (25%), glare (16.7%), and nighttime difficulties (22.3%). Dysphotopsia is commonly associated with multifocal IOLs; it occurs as a consequence of simultaneous multiple image formation, with a tendency to become less problematic over time as neuroadaptation progresses.[10–12] Furthermore, a recent French study[13] of the preliminary postoperative outcomes in 10 patients who had implantation of the Finevision diffractive trifocal IOL reported good binocular outcomes.

The purpose of the present study was to evaluate visual and subjective outcomes with the Finevision trifocal IOL. The study is 1 of very few to date regarding the use of trifocal IOLs and to our knowledge represents the largest cohort evaluated with the Finevision IOL. Given the association between multifocal IOLs and photic phenomena and previously published data indicating that visual performance may be improved with bilateral rather than unilateral implantation of multifocal IOLs,[2,14,15] all patients in our study had bilateral implantation of the trifocal IOL and per the protocol, the size of the glare area was determined using a simple halometry technique.[B]

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PATIENTS AND METHODS

This prospective interventional study included patients having routine cataract surgery and implantation of the Finevision trifocal IOL between July 2011 and October 2011. All study procedures were performed at Midland Eye Institute, United Kingdom, and the local ethics committee approved the investigation. The research adhered to the Declaration of Helsinki. After receiving an explanation of the nature and possible consequences of the study, all patients provided informed consent.

Patients with bilateral visually significant cataract scheduled for routine phacoemulsification cataract surgery and IOL implantation were enrolled in the study. Exclusion criteria included ocular disease other than cataract and previous ocular surgery or inflammation.

Intraocular Lens

The Finevision is a single-piece aspheric diffractive trifocal IOL composed of 25% hydrophilic acrylic material (Figure 1). The overall IOL diameter is 10.75 mm and the optic, 6.15 mm. The IOL is available in powers from +10.00 to +30.00 D in 0.50 D steps. The intermediate-vision and near-vision add powers are +1.75 D and +3.50 D, respectively.[A] The optic has a combination of 2 diffractive structures on the anterior surface with asymmetric light distribution between the 3 resultant useful foci; for a 20.0 D IOL and a 3.0 mm pupil diameter, the light-energy distribution to distance, near, and intermediate vision is 42%, 29%, and 15%, respectively.[9] Approximately 14% of light energy is lost at higher orders of diffraction with this IOL compared with 18% with IOLs of a typical bifocal refractive design.[3] The apodized optic increases the proportion of light directed to far vision with pupil size.

Surgical Technique

All patients had cataract surgery under topical anesthesia performed by the same experienced surgeon (S.S.). A

Figure 1. The trifocal diffractive IOL (*image provided by manufacturer*).

standard sutureless microincision phacoemulsification technique was used. The IOL was implanted in the capsular bag with a single-use injection system (Microset, Physiol). Postoperatively, topical therapy included a combination of antibiotic and steroidal agents. Second-eye surgery took place within 6 weeks of the initial operation.

Postoperative Assessment

In addition to routine postoperative checks, patients were evaluated 2 months after second-eye surgery. At this visit, the manifest refraction and logMAR uncorrected (UDVA) and corrected (CDVA) distance visual acuities were recorded. Binocular defocus curve testing was performed under photopic (85 candelas [cd]/m^2) and mesopic (5 cd/m^2) conditions from +1.50 to −4.00 D of defocus in 0.50 D steps with randomization of test chart letters using Thomson Test Chart XPert (Thomson Software Solutions) and defocus levels. Defocus lenses were inserted into a trial frame, accounting for the manifest distance refractive error, and magnification effects were accounted for in the analysis. Contrast sensitivity was measured monocularly and binocularly under photopic conditions at spatial frequencies of 3, 6, 12, and 18 cycles per degree using the CSV-1000 contrast test (Vector Vision).

Halometry was used to measure the size of the glare area for each patient monocularly and binocularly under mesopic (5 cd/m^2) conditions. A bright light–emitting diode (LED) (color temperature 3200 K) mounted at the end of a black telescopic arm was positioned in the center of a flat-screen monitor. Purpose-designed software allowed a letter (equivalent to 0.3 logMAR) to be moved along 45-degree meridians from the edge of the screen toward the glare source on a black background. The letter presented changed randomly as it moved toward the glare source; the patient was asked to identify each letter, and the eccentricity of the closest location to the LED at which the patient could correctly identify the letter was recorded. The procedure was repeated for each of the 8 meridians (in random order), allowing determination of the size of the photopic scotoma associated with the trifocal IOL.

To assess subjective satisfaction with near vision function, patients completed a validated 10-item questionnaire (Near Activity Visual Questionnaire [NAVQ]).[16] The NAVQ is designed to evaluate presbyopic corrections and requires patients to indicate their level of difficulty in performing common near-vision and intermediate-vision tasks without the use of reading spectacles (0 = no difficulty; 3 = extreme difficulty) and to rate overall satisfaction with near vision (0 = completely satisfied; 4 = completely unsatisfied). The summated score from the main body of 10 questions is adjusted to a Rasch score (from 0 to 100 logits) using a conversion table; 0 indicates no difficulty at all with any near tasks and 100 indicates extreme difficulty with all near activities.

RESULTS

This study evaluated 30 eyes of 15 patients. The mean age of the 8 men and 7 women was 69.8 years ± 10.0 (SD) (range 52 to 86 years). All patients had uneventful cataract surgery in both eyes. The IOLs were well centered in all eyes, and no pupil distortion or iris trauma occurred.

Table 1. Monocular and binocular logMAR distance visual acuities 2 months postoperatively.

Acuity	Mean ± SD	Number (%)	
		20/40 or Better	20/25 or Better
Monocular			
UDVA	0.19 ± 0.09	24* (80)	6* (20)
CDVA	0.08 ± 0.08	30* (100)	21* (70)
Binocular			
CDVA	0.06 ± 0.08	15† (100)	13† (87)

CDVA = best-corrected distance visual acuity; UDVA = uncorrected distance visual acuity
*Eyes
†Patients

Table 1 shows the mean monocular and binocular distance visual acuities and the distance vision efficacy. The mean monocular refractive correction was 0.27 ± 0.36 D sphere (range −0.25 to +1.00 D) and −0.48 ± 0.45 D cylinder (range 0.00 to −1.50 D). Figure 2 shows the binocular mean defocus curves under photopic and mesopic conditions. Under both lighting conditions, the optimum visual acuity results were obtained at 0.00 D defocus (equivalent to distance-vision viewing), with a second peak at −2.50 D (equivalent to near viewing at 40 cm). No distinct peak in the intermediate zone was present for either lighting level, although the range of clear vision (0.3 logMAR or better) extended from +1.00 to −2.50 D of defocus, with no sharp drop in acuity in the intermediate zone under the photopic condition. Although in general the mean visual acuities were better under the photopic testing condition, the differences between lighting conditions were not significant except at −1.50 D defocus ($P = .008$), corresponding to an intermediate viewing distance.

Figure 3 shows the monocular and binocular distance contrast sensitivity (log10) under photopic conditions. Binocular contrast sensitivity values were significantly better than monocular values at all spatial frequencies tested ($P < .05$). No significant differences in contrast sensitivity values between right eyes and left eyes were found at any spatial frequency ($P > .05$).

Postoperatively, no patient reported adverse photic phenomena. Figure 4 shows the halometry results; the magnitude of the mean monocular and binocular photopic scotomas measured under mesopic conditions is shown. The mean photopic scotomas were generally uniform in shape, extending binocularly between 0.69 ± 0.24 degrees and 1.03 ± 0.20 degrees for all 8 meridians.

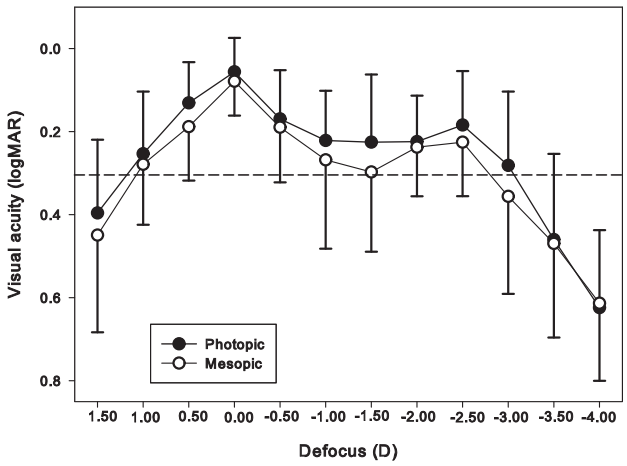

Figure 2. Binocular mean defocus curves under photopic conditions and mesopic conditions. Error bars represent ±1 SD. The dotted reference line at 0.3 logMAR equates to the European driving standard.

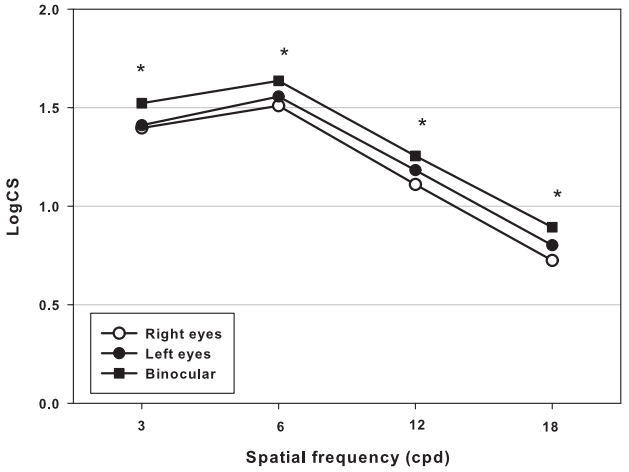

Figure 3. Monocular and binocular contrast sensitivity functions under photopic conditions. The asterisks represent a statistically significant difference between monocular values and binocular values (cpd = cycles per degree).

The NAVQ scores for subjective satisfaction with near vision were high, with a mean Rasch score of 15.9 ± 10.7 logits (0 = completely satisfied; 100 = completely unsatisfied) (range 0 to 33.3). The mean overall satisfaction score with near vision (0 = completely satisfied; 4 = completely unsatisfied) was 0.7 (range 0 to 2).

DISCUSSION

Multifocal IOLs are becoming more widely used as patients having cataract surgery or lens exchange have increasing functional expectations and a desire for postoperative spectacle independence.[17–19] Current diffractive multifocal IOLs typically provide good vision at distance and near[1,19,20] but have the disadvantages of a bifocal design, which can lead to difficulties with intermediate vision[9,A] (eg, during computer use) and is associated with frequent reports of dysphotopsia.[5,21] The current study evaluated the postoperative visual outcomes and patient satisfaction with the Finevision IOL, a new diffractive trifocal IOL design.[9]

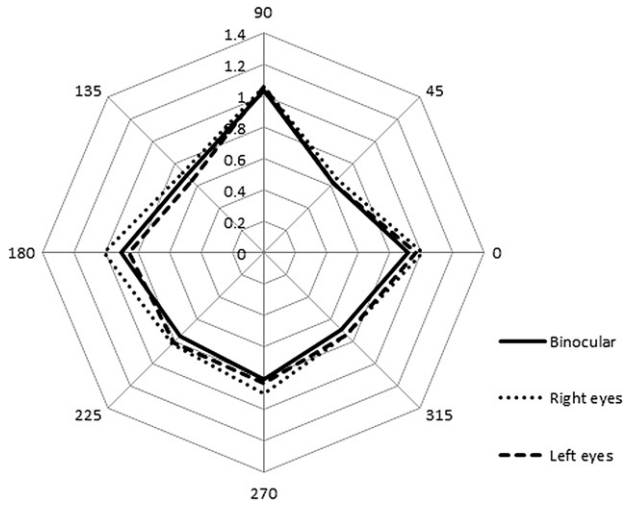

Figure 4. Size of monocular and binocular photopic scotomas measured using halometry under mesopic conditions. The *y*-axis represents the extent of scotoma from the glare source (degrees). The radial axis represents the visual-field meridian (degrees).

To our knowledge, this is 1 of only 2 studies to report the clinical outcomes in a cohort that had binocular implantation of diffractive trifocal IOLs. The mean monocular UDVA (0.19 ± 0.09) and CDVA (0.08 ± 0.08) results are similar to the values reported by Voskresenskaya et al.[10] (0.13 and 0.07, respectively; converted from decimal values) with predominantly monocular implantation of the MIOL-Record IOL. Furthermore, our visual acuity outcomes are comparable to those achieved with several bifocal-design diffractive IOLs.[1,5,20] However, both our mean binocular UDVA and CDVA are lower than those reported by Lesieur[13] with the same IOL (mean 0.00 ± 0.01 and 0.00 ± 0.00, respectively); it is likely that this difference is due to the older population in the present study (69.8 ± 10.0 years compared with 59.3 ± 4.1 years). The optical performance of the human eye is known to decline with age,[22] with a resultant reduction in visual acuity for elderly phakic and pseudophakic individuals.[23,24]

The mean and range of postoperative refractive cylinders in the present study (−0.48 ± 0.45 D and 0 to −1.50 D, respectively) closely agree with results in several studies that assessed the clinical outcomes

with IOLs having diffractive profiles.[2,5,20] In a study by Fernández-Vega et al.,[2] the mean postoperative refractive cylinder was −0.51 ± 0.78 D with the Acri.Tec 447D IOL. Alió et al.[5] found a mean of −0.46 ± 0.46 D (range 0 to −1.50 D) with the Acri.Lisa 366D IOL. In the future, toric trifocal IOL designs, rather than limbal or corneal relaxing incisions, could provide a predictable solution for patients with significant preoperative corneal astigmatism rather than excluding patients with significant astigmatism.

Binocular defocus curve testing indicated an extended range of clear vision rather than distinct peaks corresponding to the 1.75 D and 3.50 D adds. The mean visual acuity was 0.3 logMAR or better from +1.00 to −2.50 D defocus under both photopic and mesopic conditions, with no apparent peak in visual acuity in the intermediate zone. Such a finding may be expected given the asymmetric light distribution of the Finevision IOL, in which a relatively small proportion of light is available for intermediate vision compared with the proportion available for distance and near (eg, 42%, 29%, and 15% directed to distance, near, and intermediate foci, respectively, for a 3.0 mm pupil[9]). As pupil size increases, a greater proportion of light is directed to the distance focus due to the apodized optic so that for a 5.0 mm pupil, only approximately 5% of light is available for intermediate vision. The reduced light available for intermediate vision with larger pupil sizes is likely to be the cause of the significantly poorer visual acuity under mesopic conditions than under photopic conditions at −1.50 D defocus. There were no significant differences in visual acuity between mesopic conditions and photopic conditions at any of the other defocus levels tested.

In this study, binocular contrast sensitivity values were significantly higher than monocular values at all spatial frequencies. The well-known effect of binocular summation explains the difference between monocular and binocular results and is in agreement with previous reports of diffractive IOL outcomes in which several authors advised binocular implantation to optimize contrast sensitivity.[2,15,25] Multifocal IOLs have been reported to cause up to a 50% reduction in contrast sensitivity[26]; however, our monocular contrast sensitivity values were within the normal range for older adults obtained with the CSV-1000 and described by Pomerance and Evans[27]. However, they were slightly below their mean values; this could be partly due to the older cohort in the present study (mean 69.8 ± 10.0 years versus 63.9 ± 12.2 years) and normal age-related retinal and neural changes.[28,29]

Photic phenomena frequently associated with multifocal IOLs, including glare, halos, and positive dysphotopsia, can affect the quality of life[30] and are approximately 3.5 times more common with multifocal IOLs than with monofocal IOLs.[31] In the present study, no patient reported photic phenomena, suggesting that the design of the Finevision IOL, with increasing far vision dominance as pupil size increases, may be effective in minimizing halos and glare perception. However, our cohort size was limited to 15; a larger scale study would be required to gain a full insight into the frequency of adverse photic phenomena with the Finevision IOL. The mean size of the photopic scotomas (monocular extent from glare source ranged from 0.6 ± 0.3 degrees to 1.1 ± 0.2 degrees) in the present study compares favorably with previous measures using the same technique in patients with a multifocal and an accommodating IOL design.[C] Subjective satisfaction with uncorrected near vision measured with the NAVQ questionnaire was high in the present study (mean 15.9 ± 10.7 logits). The NAVQ test[16] is designed to allow a more standardized comparison of presbyopia-correction strategies by questioning patients about their ability to perform common near tasks, such as reading mail and seeing the display on a computer without an additional near-vision correction. Rasch-scaled scores may range from 0 (no difficulty at all with near vision) to 100 (extreme difficulty with all near tasks), and the mean value obtained with the Finevision trifocal IOL showed a higher level of patient satisfaction with near vision than reported by Buckhurst et al.[16] for other multifocal IOLs (mean 18.9 ± 13.2 logits) and accommodating IOLs (mean 34.2 ± 12.1 logits). The NAVQ includes questions related to intermediate and distance visual function (eg, using a computer and performing hobbies such as gardening or playing cards); the improved score with the Finevision IOL compared with other presbyopia-correcting IOLs may be due in part to the improved intermediate visual ability provided by the 1.75 D intermediate add power.

In conclusion, the Finevision trifocal IOL provided a good standard of distance vision acuity and intermediate and near visual function, as shown by defocus curve testing. The increasing far-vision dominance of the IOL as pupil size increases may be effective in reducing the photic phenomena frequently associated with multifocal IOLs. Near-vision satisfaction in this cohort of patients with bilateral implantation was high, which along with the clinical measures, suggests that the Finevision IOL is an effective method of providing good distance, near, and intermediate visual ability.

WHAT WAS KNOWN

- Bifocal diffractive IOLs can provide good uncorrected distance and near acuities; however, intermediate vision may be poorer.
- Multifocal IOLs are also associated with frequent reports of dysphotopsia.

WHAT THIS PAPER ADDS

- Bilateral implantation of the new trifocal diffractive IOL can provide an extended range of clear vision, with high levels of patient satisfaction relating to uncorrected near vision and no reports of dysphotopsia in this cohort.

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Intra-ocular diathermy forceps

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ABSTRACT.

Purpose: **The purpose of this study was to develop intra-ocular diathermy forceps and test them on perfused porcine cadaver eyes.**

Methods: **We designed two types of 23-gauge intra-ocular bipolar diathermy forceps by modifying commercially available membrane peeling forceps. In the first type, the emitting electrode is connected to one-half of the core and the return electrode to the other half, with one jaw of the forceps attached to each half. In the second type, the emitting electrode is attached to the core and both jaws of the forceps, and the return electrode to the surrounding tube. We compared the new diathermy forceps to conventional intra-ocular diathermy, on perfused porcine cadaver eyes. First-order retinal artery and vein closure was confirmed both by a perfusion study and by histology of the treated vessels.**

Results: **Type 1 diathermy forceps closed retinal arteries and veins more successfully (five of five and five of five successful treatments, respectively) than Type 2 diathermy forceps (five of five and four of five, respectively) and conventional diathermy (three of five and four of five, respectively). Less energy was used with Type 1 compared to Type 2 and conventional for artery closure (1.5 ± 0.0 versus 4.6 ± 3.3 versus 2.1 ± 0.8 joules, respectively) and vein closure (1.5 ± 0.0 versus 5.4 ± 4.6 versus 2.4 ± 0.8 joules, respectively). Histology of the treated vessels confirmed the perfusion study results.**

Conclusion: **We designed two types of a new multifunctional intra-ocular instrument with the ability to peel membranes and to grasp, compress and coagulate retinal blood vessels. Both types pose operational advantages compared to current conventional intra-ocular diathermy.**

Key words: coagulation – intra-ocular diathermy forceps – perfusion – porcine eye model – retinal blood vessels – retinal hemangioblastoma

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Introduction

Intra-ocular diathermy was pioneered in the 1970s (Parel et al. 1974). Monopolar diathermy coagulated blood vessels, but caused collateral retinal damage. Bipolar diathermy had narrower coagulation boundaries (Tate et al. 1975; Parel et al. 1983). There have been no advances in intra-ocular diathermy design since the 1980s, in contrast to laparoscopic surgery, where bipolar diathermy forceps are routinely used since the 1990s (Entezari et al. 2007).

Current bipolar intra-ocular diathermy probes have multiple weaknesses, which become evident during attempted closure of hemangioblastoma feeder vessels (van Overdam et al. 2017). The conventional diathermy probe is point-shaped. The surgeon must push on the blood vessel with the probe to close it and then coagulate it. High energy levels are needed to coagulate the distal vessel wall, leading to collateral damage. Secondly, the tip of the diathermy probe blocks the surgeon's view of the blood vessel and coagulation reaction, unless the surgeon removes the probe from the treated area. Thirdly, in case of iatrogenic bleeding, there is unavoidable delay between the removal of the instrument involved in the bleeding episode and the introduction of the diathermy probe into the eye. This makes bleeding more difficult to control.

Therefore, we designed a new intra-ocular instrument combining the ability to apply mechanical compression from opposite sides, a diathermy function and a membrane peeling function, which addresses these weaknesses.

Materials and Methods

Two types of bipolar diathermy forceps were developed by modifying available single-use 23-gauge peeling forceps (Vitreq, the Netherlands; Bausch & Lomb, US). In Type 1, the emitting electrode is connected to one-half of the core and the return electrode to the other half, with one jaw of the forceps attached to each half of the core. In

Type 2, the emitting electrode is attached to the core and both jaws of the forceps and the return electrode to the surrounding tube. Both types retain membrane peeling function.

The diathermy forceps were tested *ex vivo* on perfused porcine cadaver eyes. The eyes were harvested at a local abattoir immediately after killing the animal and transported in heparinized saline (50 units/ml), in melting ice. The time between eye harvesting and preparation was less than 6 hr.

The ophthalmic artery was cannulated with a 23-gauge cannula. The retinal vessels were accessed via an open-sky approach. The vitreous was segmented with No 05-0740 scissors (Lawton, Germany) and was removed, as much as possible, from the retinal surface, with cotton buds. The eyes were filled with perfluorodecalin (DORC, Netherlands). A blood column was present in the retinal vessels at the end of the process.

We powered the diathermy instruments with a bipolar coagulator (450 kHz) (Aesculap, Germany), delivering power in 0.1 watt steps. The surgeon adjusted energy duration by foot pedal. A starting power of 1.5 watt was chosen based on published recommendations (Parel et al. 1983).

Fifteen porcine eyes were used, five with Type 1, five with Type 2 and five with a conventional disposable 23-gauge bipolar diathermy (Kirwan Surgical Products, US). We treated a first-order branch of the superior or inferior retinal artery and vein, by either compressing the vessel lumen from both sides with the diathermy forceps or by pushing from above with conventional diathermy, until we saw complete disruption of the blood column, caused by coagulation. We confirmed the results of the coagulation treatment by perfusing the eyes with 100 ml heparinized (50 IU/ml) succinylated gelatin 4% (B.Braun, Germany) with 30 mg of fluorescein added to it, at 0.1 ml/min, using a microprocessor-controlled dispensing pump (ALT, US).

The eyes underwent standard formalin fixation and paraffin embedding prior to histological examination.

Results

The results of the perfusion study and the energy required to close retinal arteries and veins with conventional, Type 1 and Type 2 diathermy forceps, are given in Table 1.

Two coagulation applications were needed with conventional diathermy in two of five eyes (arteries) and three of five eyes (veins) because the study

Table 1. *Ex vivo* performance of the diathermy forceps compared to conventional diathermy.

		Closure rate		Energy (joules ± SD)		Time (seconds ± SD)	
Diathermy Type	Eyes (*n*)	Artery	Vein	Artery	Vein	Artery	Vein
Conventional diathermy probe	5	3/5	4/5	2.1 ± 0.8	2.4 ± 0.8	1.4 ± 0.5	1.6 ± 0.5
Type 1 diathermy forceps	5	5/5	5/5	1.5 ± 0.0	1.5 ± 0.0	1.0 ± 0.0	1.0 ± 0.0
Type 2 diathermy forceps	5	5/5	4/5	4.6 ± 3.3	5.4 ± 4.6	1.2 ± 0.8	1.4 ± 1.1

SD = standard deviation.

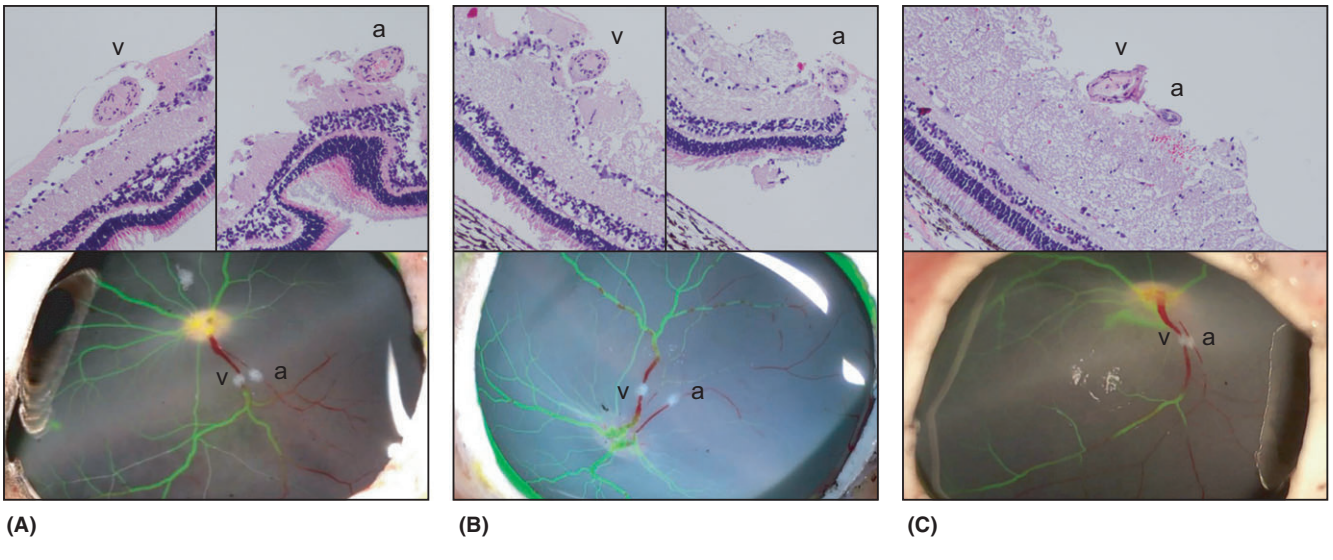

Fig. 1. Fundus photographs and histology slides of coagulated porcine retinal blood vessels. Histology slides (above) and fundus photographs (below) of porcine retinal arteries (labelled a) and veins (labelled v) coagulated with conventional diathermy (panel A), Type 1 diathermy forceps (panel B) and Type 2 diathermy forceps (panel C). In the fundal photographs, the blood columns in the artery and vein have been interrupted by coagulation. The coagulated site and the blood vessel downstream from it show no flow during perfusion of the ophthalmic artery with fluorescein-stained fluid. The histology slides (magnification 100x; haematoxylin and eosin stain) show coagulated and closed retinal blood vessels following application of diathermy. Retinal detachment is a common artefact because of preparation of the eye for the perfusion study and/or tissue processing for histological examination.

investigator did not see sufficient coagulation reaction after the first application.

For Type 2 forceps, the starting power was increased to 4.0 watt because there was no diathermy effect with lower power in the first two eyes. More vitreous was removed from the retinal surface in the remaining three eyes, which reduced the power needed to close the vessels. Use of Type 2 diathermy forceps can be seen in the Video Clip S1.

Histology of the treated vessels confirmed the results of the perfusion study. Both types of forceps closed retinal arteries and veins more effectively than conventional diathermy. Fundus photographs and histology slides of coagulated porcine retinal blood vessels, coagulated with conventional, Type 1 and Type 2 diathermy forceps, are shown in Figure 1.

Comment

This is the first report on two types of a new intra-ocular bipolar diathermy instrument, since the publication by Parel et al. (1983) on the conventional bipolar diathermy probe. Both types, in an *ex vivo* proof-of-concept study, grasp, compress and coagulate retinal blood vessels more effectively than conventional diathermy.

Our design successfully addresses weaknesses of conventional diathermy. Firstly, the blood vessel can be compressed between the jaws of the forceps and be coagulated using lower energy. Secondly, the design ensures visualization of the target blood vessel during the entire coagulation process so the minimum energy necessary is used. The *ex vivo* nature of the model allows for energy requirement comparison between the diathermy forceps and conventional diathermy. The comparison favours the diathermy forceps. Thirdly, the diathermy forceps can be used as regular micro-forceps, with diathermy continuously available for tissues that are being manipulated and at risk of sudden bleeding.

The presence of vitreous close to blood vessels increased the energy requirements for coagulation when using Type 2 forceps. This may be because the space between the emitting and return electrodes (the jaws and the tube of the forceps) can be occupied by vitreous, which interferes, due to its higher impedance than water, with the electric current. In contrast, in Type 1 forceps, the emitting and return electrodes are connected to the jaws of the forceps with the target blood vessel, but no vitreous, directly between them.

We have designed a new intra-ocular instrument combining the ability to apply mechanical compression on opposite walls of a blood vessel, with a bipolar diathermy and membrane peeling function. This enables the surgeon to have, in effect, multiple instruments, including more effective diathermy, in one hand, meaning that there is no delay between onset of bleeding and coagulation. This will facilitate intraocular vascular control.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Video Clip S1. Use of the diathermy forceps on a porcine retinal vein and artery. Subsequent perfusion of the ophthalmic artery with fluorescein-stained infusate shows that the coagulated sites and the blood vessels, downstream from those sites, show no flow.