Acta Ophthalmologica

Comparison of 23-gauge sutureless sclerotomy architecture and clinical outcomes in macular and non-macular surgery using spectral-domain optical coherence tomography

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ABSTRACT.

Purpose: **To compare the 23-gauge (23-G) sutureless vitrectomy incision architecture in macular and non-macular surgery, using anterior segment spectral-domain optical coherence tomography (SD-OCT), and to evaluated its influence on clinical outcomes.**

Methods: **A prospective, observational case series of 43 patients who underwent primary transconjunctival 23-G pars plana vitrectomy (PPV) for macular and non-macular diseases. All sclerotomy wounds were imaged 1 day after surgery using the anterior segment module of SD-OCT (OCT Spectralis; Heidelberg Engineering, Heidelberg, Germany). Sclerotomy architecture, including good wound apposition, presence of gaping and misalignment of the roof and floor of the incisions were evaluated. Preoperative, intraoperative and postoperative medical record data were also prospectively collected.**

Results: **Incision gaping and misalignment of the roof and floor occurred more frequently in the superotemporal and superonasal quadrants than in the inferotemporal quadrant ($p < 0.05$) and was more frequent in the non-macular group than in the macular group ($p < 0.05$). The incidence of incision gaping increased significantly as the incision angle increased. In the macular group, the mean postoperative intraocular pressure (IOP) did not change from the preoperative value, whereas in the non-macular group, the mean IOP decreased significantly from 15.09 ± 2.58 mmHg preoperatively to 12.18 ± 3.25 mmHg on the first postoperative day ($p < 0.005$). The mean IOP did not differ significantly between the two groups of surgery at 1 week, and at 1 month postoperatively.**

Conclusions: **In 23-G PPV, non-macular surgery is associated with a significant postoperative IOP decrease in comparison with macular surgery, which could be explained by the most remodelled wound architecture.**

Key words: 23-gauge sutureless vitrectomy – anterior segment optical coherence tomography – intraocular pressure – non-macular and macular surgery – sclerotomy architecture – spectral domain

Acta Ophthalmol. 2013: 91: e203–e210

doi: 10.1111/aos.12015

Introduction

The sutureless vitrectomy provides many advantages over conventional 20-gauge (20-G) vitrectomy, including shorter surgical time, improved patient comfort, reduced intraocular inflammation, faster wound healing, less conjunctival scarring, less surgically induced astigmatism and faster visual recovery (Lakhanpal et al. 2005; Rizzo et al. 2006; Romero et al. 2006; Chen 2007; Fine et al. 2007; Okamoto et al. 2007; Androudi et al. 2012; Sandali et al. 2011). However, in contrast to 20-G vitrectomy, potential wound leakage and postoperative hypotony remain problems associated with sutureless vitrectomy, especially when extensive intraocular manipulations are performed (Framme et al. 2012; Lin et al. 2011). Some studies reported an increased risk of postoperative hypotony and leakage in non-macular surgery compared with macular surgery (Woo et al. 2009; Lin et al. 2011); however, they did not compare the *in vivo* sclerotomies architecture between these two groups. Moreover, none of them evaluated the early postoperative variation in intraocular pressure (IOP), which is more relevant to evaluating the consequences of wound leakage and may be the only hint of this type of complication.

Recently, Taban et al. used the visante anterior segment optical coherence tomography (OCT) (Carl Zeiss, Dublin, CA, USA) to evaluate the morphology of 23-gauge (23-G) sutureless vitrectomy wounds in the postoperative period and demonstrated that it was a valuable tool in the study of surgical wounds (Taban et al. 2009). Several studies assessing the scleral incisions using anterior segment OCT have since been published; however, most of them used an anterior segment *time-domain* OCT and did not compare macular surgery (e.g. epiretinal membrane and macular hole) and non-macular surgery (e.g. retinal detachment) (Chen et al. 2010; Guthoff et al. 2010; Sawada et al. 2011; Yamane et al. 2011; Awan et al. 2012).

The purpose of this prospective study was to compare the architecture of 23-G sutureless sclerotomies in macular and non-macular surgery using anterior segment spectral-domain optical coherence tomography (SD-OCT) and its influence on postoperative outcomes, especially postoperative IOP variation.

Patients and Methods

Subjects

Between July 2010 and October 2010, patients with various vitreoretinal diseases treated using primary transconjunctival 23-G sutureless pars plana vitrectomy (PPV) were consecutively included in the study. Patient diagnosis categories were split into two broader categories. Macular diagnoses were defined as surgeries for epiretinal membrane removal, vitreomacular traction syndrome or macular hole repair. Non-macular diagnoses were defined as surgeries for rhegmatogenous retinal detachment, tractional retinal detachment, proliferative diabetic retinopathy and dislocated lens. Patients with a history of prior scleral buckling, PPV or presence of conjunctival or scleral scarring and other coexisting ocular disorders such as glaucoma and uveitis were not included in the study. We also did not include patient who needed combined cataract extraction. Patients were operated on by two experienced vitreoretinal surgeons (R.A. and C.M.) using the same surgical technique at the Quinze-Vingts National Ophthalmology Center (Paris, France).

This study was approved by the Ile-de-France Institutional Review Board for Human Subjects Research (CCP 5, No 10793), and the study adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from all the eligible patients before operations.

Surgical procedure

All patients underwent three-port PPV with the Alcon 23-G trocar/cannula microvitrectomy system (Alcon Laboratories Inc., Fort Worth, TX, USA) under peribulbar anaesthesia using a 50% mixture of lidocaine 2% and bupivacaine 0.75%. The conjunctiva and the Tenon capsule were anteriorly displaced away from the intended sclerotomy site using forceps to avoid direct communication between entry sites. All incisions were made by inserting trocars first at an oblique angle between 20° and 30° tangential to the scleral surface, 3.5 mm posterior to the corneoscleral limbus, with the bevel up. Once reaching the trocar sleeve, the cannula was rotated 90° perpendicular to the globe towards the midvitreous cavity. The cuff of the cannula was held in place by forceps, and the trocars were removed from the eye. The infusion cannula was placed in the inferotemporal quadrant, while the two other cannulas were placed in the superotemporal and superonasal quadrants. All vitrectomies were performed with the Accurus vitrectomy system and Accurus cutters with speeds up to 2500 cuts per minute (Alcon Laboratories, Inc.). Following the vitrectomy procedure, patients underwent when needed a gas–fluid exchange based on the surgical indication. In cases that required internal tamponade, intravitreal air, gas [sulfurhexafluoride (SF6; 20%) hexafluoroethane (C2F6; 16%) perfluoropropane (C3F8; 14%)] or silicone oil (Acri.Sil-ol 5000, 5000 cps; Acri.Tec, Hennigsdorf, Germany) injection was performed. In case of non-macular surgery, all cannulas were cleared from inside by shaving the vitreous surrounding them using depressed vitrectomy, whereas only central vitrectomy was performed in case of macular surgery. At the end of surgery, the cannulas were withdrawn from the sclera and the conjunctiva was pushed laterally with a cotton tip. The infusion line was clamped at the time the cannulas were removed and unclamped afterwards. Firm pressure was applied with a cotton-tip applicator onto the sclerotomy sites to enhance sclerotomy sealing and to return the displaced conjunctiva to its original position. A cellulose sponge (Weck-Cel; Medtronic Xomed Inc, Jacksonville, FL, USA) was applied to the sclerotomy site to identify any vitreous wick. Each of the wounds was then carefully inspected for leakage indicated by the formation of subconjunctival bleb or hypotony. If leakage was noted, further pressure was applied with a sterile cotton-tipped applicator to the site until leakage ceased. If leakage continued beyond 1 min, a Vicryl 7-0 (polyglactin 910; Ethicon Inc, Somerville, NJ, USA) suture was performed to close the scleral wound after a small opening of the conjunctiva. Patients who needed suture of one of their incisions were excluded from the analysis.

Outcome measures

Preoperative, intraoperative and postoperative medical data were prospectively collected. The data collected included patient age; gender; eye laterality; diagnosis; preoperative refractive error, preoperative and postoperative best-corrected visual acuity (BCVA) at 1 month; preoperative and postoperative IOP at 1 day, 1 week, and 1 month following surgery; duration of the surgery; wound self-sealing; and intraoperative and postoperative complications. The surgical duration was defined as the time between insertion and removal of the lid speculum. It was assessed by the surgeon and his assistant and was recorded in the patients' operative reports. Snellen visual acuity was converted into logarithm of the minimum angle of resolution (LogMAR) for statistical analysis. Intraocular pressure was measured with the Goldmann applanation tonometer.

Postoperative complications included severe hyper- or hypotony, suprachoroidal haemorrhage, retinal tear, retinal detachment, vitreous haemorrhage and endophthalmitis. Severe postoperative hypotony and hypertony were defined as IOP <6 and >30 mmHg, respectively.

Optical coherence tomography

Optical coherence tomography examinations were performed 1 day after surgery by a single examiner (R.T.) after instillation of oxybuprocaine (Faure; Novartis Pharma SAS, Rueil Malmaison, France). The sclerotomy wounds were imaged with the anterior segment module of SD-OCT (OCT Spectralis; Heidelberg Engineering, Heidelberg, Germany) with an axial resolution of 7 μm, transverse resolution of 14 μm and scan speed of 40 000 scans per second. The beam was carefully aligned to scan across the pars plana region to traverse the centre of the incisions and rotated parallel to the limbus to follow the paths of the incisions (Fig. 1A). Two-dimensional images were captured when the whole tract was displayed in a cross-sectional profile. The summation of five images and the 'eye tracking' modules were activated during the examination.

Image analysis

All images were analysed using the 'heat' mode of the OCT Spectralis imaging system. The incision length and the conjunctiva thickness were measured using analysis software on the OCT Spectralis imaging system, and the incision angle was measured using IMAGEJ software (version 1.43u; National Institutes of Health, Bethesda, MD, USA). The distance between the two end points of the scleral tunnel determined the incision length. The angle subtended from the scleral tunnel to the tangent line of the sclera defined the incision angle. Other incision characteristics were also examined including evidence of good wound apposition, wound gaping (either externally or internally), misalignment of the roof and floor of the incision, local ciliochoroidal detachment and vitreous incarceration. Loss of wound apposition was defined by the presence of wound gaping or misalignment of the roof and floor of the incision (Figs 1 and 2).

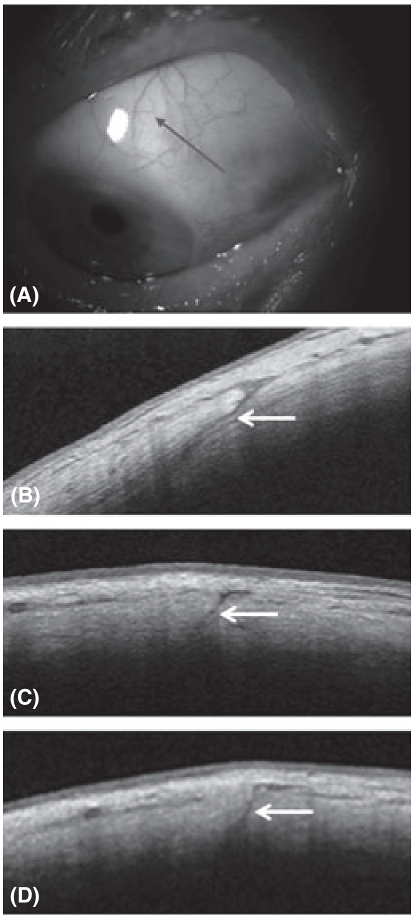

Fig. 1. (A) Orientation of the optical coherence tomography (OCT) beam parallel to the limbus (grey arrow). Spectral-domain OCT images showing different incision angles, (B) Very oblique incision, (C) intermediate angle and (D) straight angle.

Statistical analysis

Results are presented as mean ± standard deviation (SD) for continuous variables and as proportions (%) for categorical variables. The distribution pattern of the variables included was compared with a theoretical normal distribution using a Kolmogorov–Smirnov test. The Student *t*-test and the non-parametric Mann–Whitney test were used to compare continuous data. Paired Student *t*-test and Kruskal–Wallis test were used to statistically evaluate comparisons between preoperative and postoperative logMAR VA and IOP when appropriate. For binary outcomes, the stratified Cochran chi-square test and the Fisher exact test were used for inter-group comparisons of proportions when appropriate. p-values of 0.05 or less were considered statistically significant. Statistical analysis was carried out using SPSS for Windows version 16.0 (SPSS, Inc., Chicago, IL, USA).

Results

General characteristics

Forty-four patients met the inclusion criteria. One patient was excluded from analysis because he needed suture of at least one of his sclerotomies. This patient was a 64-year-old man who was treated for tractional retinal detachment due to proliferative diabetic retinopathy. The incisions were not imaged after surgery.

Forty-three eyes of 43 patients (20 males and 23 females) were finally included for analysis. The mean patient age was 65.05 ± 12.83 years. Twenty-one patients underwent macular surgery, while 22 patients underwent non-macular surgery. The indications for 23-G vitrectomy are shown in Table 1.

The baseline characteristics recorded for the patients in the two surgical groups (macular versus non-macular) are summarized in Table 2. No significant differences in baseline characteristics between the two surgical groups were apparent, except for the preoperative BCVA and the preoperative refractive error.

Operating time

The mean surgical time (± SD) was significantly shorter in the group of patients who underwent macular surgery than in the group of patients who underwent non-macular surgery: 22.05 ± 6.64 min versus 51.82 ± 13.08 min ($p < 0.001$, Student *t*-test).

Incision structure

The characteristics of the incision in each quadrant are listed in Table 3. The incision angle was higher in the superotemporal and superonasal quadrants (50.70° ± 13.80°) than in the inferotemporal quadrant (47.60° ± 11.03°), but the difference was not significant ($p = 0.203$, Student *t*-test). The incision angle was significantly more oblique in the macular group

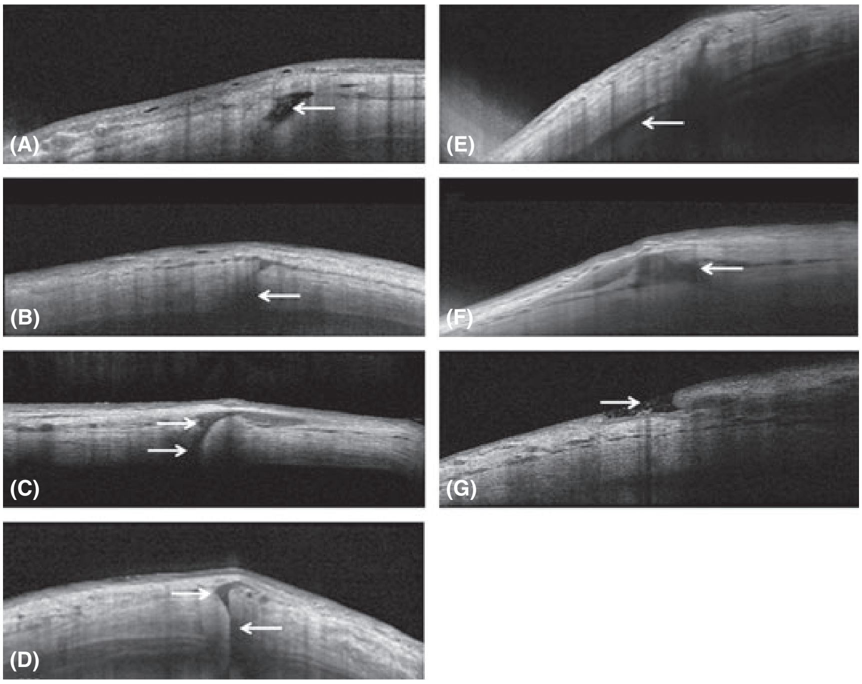

Fig. 2. Spectral-domain optical coherence tomography images showing examples of absence of good apposition and other complications. (A) External gaping, (B) internal gaping, (C) Both external and internal gaping, (D) misalignment of the incision roof and floor, (E) local ciliochoroidal detachment, (F) vitreous incarceration and (G) conjunctival lesion.

Table 1. Indications for 23-G vitrectomy in macular and non-macular groups.

Indications	*n* (%)
Macular group	
Epiretinal membrane	19 (44.2)
Macular hole	1 (2.3)
Vitreomacular traction	1 (2.3)
Nonmacular group	
Rhegmatogenous retinal detachment	13 (30.2)
Tractional retinal detachment	6 (14.0)
Proliferative diabetic retinopathy	2 (4.7)
Dislocated lens	1 (2.3)

than in the non-macular group, in each quadrant (Table 3). As right-handed surgeon uses right hand more frequently than left hand, we compared the incision angle of superior right and superior left. No statistical significance was found between these two incision angles: 49.84° ± 13.88° versus 51.16° ± 13.77° (p = 0.203, Student *t*-test). No statistical significance was found between the different quadrants or between the two surgical groups in terms of incision length (Table 3).

There was significantly more misalignment of the incision roof and floor in the superotemporal and superonasal quadrants (13/86) than in the inferotemporal quadrant (1/43) (p = 0.034; Fisher exact test), and this occurred more frequently in the non-macular group compared with that in the macular group: 1/63 (1.6%) versus 13/66 (19.7%) (p = 0.001, Fisher exact test).

Incision gaping occurred at an incidence of 26.7% in the superotemporal and superonasal quadrants (23/86) and 11.6% in the inferotemporal quadrant (5/43) (p = 0.0496; chi-square test). Eleven incisions exhibited both external and internal gaping. Incision gaping was more frequent in the non-macular group in comparison with the macular group, in all quadrants (Table 3). The incision angle was significantly greater in sclerotomies with internal or external gaping (*n* = 28) in comparison with sclerotomies without gaping (*n* = 101): 57.07° ± 12.66° versus 47.61° ± 12.36° (p < 0.001, Student *t*-test). We categorized the sclerotomies (*n* = 129) into six groups according to the incision angle: 21–30° (*n* = 11), 31–40° (*n* = 22), 41–50° (*n* = 48), 51–60° (*n* = 26), 61–70° (*n* = 12) and 71–80° (*n* = 11). We found that the incidence of incision gaping increased significantly as the incision angle increased (Fig. 3).

The mean thickness of the conjunctiva was significantly lower in the macular group compared with the non-macular group: 251.2 ± 50.5 μm versus 297.0 ± 65.0 μm (p = 0.014, Student *t*-test). No statistical significance was found between the different quadrants or between the two surgical groups in terms of vitreous incarceration and local ciliochoridal detachment.

Visual acuity

The preoperative BCVAs (LogMAR; mean ± SD) were 0.85 ± 0.57 in the macular group and 1.55 ± 0.72 in the non-macular group, which improved to 0.46 ± 0.32 and 0.64 ± 0.25, respectively, at 1 month postoperatively (p < 0.001, paired Student *t*-test). The VA improvement (LogMAR; mean ± SD) was significantly higher in the non-macular group than in the macular group: −0.91 ± 0.70 (*n* = 22) versus −0.39 ± 0.34 (*n* = 21) (p = 0.004, Student *t*-test).

Intraocular pressure variation

None of the patients had a hypotensive treatment during the first postoperative month. The mean IOP values before and after surgery are summarized in Table 4. In the macular group, the mean postoperative IOP did not change from the preoperative value (Fig. 4). In the non-macular group, the mean IOP decreased significantly from 15.09 ± 2.58 mmHg preoperatively to 12.18 ± 3.25 mmHg on the 1st day postoperatively and to 14.09 ± 2.49 mmHg 8 days after surgery (Fig. 4). The mean IOP did not differ significantly between the two groups of surgery preoperatively, at 1 week, or at 1 month postoperatively (Table 4). However, on postoperative day 1, the mean IOP was significantly higher in the macular group than in the non-macular group (Table 4). Furthermore, the IOP variation on day 1 and day 8 was greater in the non-macular group than in the macular group (Table 4).

Complications

No intraoperative or postoperative complications occurred in this study.

Table 2. Patient characteristics.

Characteristics	Macular surgery (n = 21)	Nonmacular surgery (n = 22)	p-value
Age (mean ± SD, years)	66.14 (13.65)	64.00 (12.22)	0.590*
Gender			
Male (%)	8 (38.1)	12 (54.5)	0.364†
Female (%)	13 (61.9)	10 (45.5)	
Preoperative intraocular pressure (mean ± SD, mmHg)	14.24 (3.10)	15.09 (2.58)	0.331*
Preoperative best-corrected visual acuity (mean ± SD, LogMAR)	0.85 (0.57)	1.55 (0.72)	**0.001***
Preoperative refractive error (diopter)	−0.24	−2.26	**< 0.001***
Laterality			
Right (%)	11 (52.4)	10 (45.5)	0.763†
Left (%)	10 (47.6)	12 (54.5)	

SD = standard deviation, LogMAR = logarithm of minimum angle of resolution.
The values in bold indicate statistical significance ($p < 0.05$).
* Student t-test.
† Fisher exact test.

Table 3. Comparison of incision characteristics in the superonasal, superotemporal and inferotemporal quadrants.

Quadrant	Macular surgery (n = 21)	Nonmacular surgery (n = 22)	p-value
Incision angle (mean ± SD, degrees)			
Superotemporal	44.67 (12.07)	56.32 (12.84)	**0.004***
Superonasal	44.29 (11.47)	56.95 (13.81)	**0.002***
Inferotemporal	43.14 (6.76)	51.86 (12.78)	**0.008***
Incision length (mean ± SD, μm)			
Superotemporal	1159 (213.0)	1141 (182.1)	0.767*
Superonasal	1108 (180.3)	1088 (161.3)	0.702*
Inferotemporal	1182 (196.1)	1125 (117.6)	0.255*
Conjunctival epithelial thickness (mean ± SD, μm)			
Superotemporal	269.6 (65.6)	297.0 (77.7)	0.219*
Superonasal	230.7 (61.0)	295.8 (72.9)	**0.003***
Inferotemporal	253.3 (49.2)	298.3 (65.4)	**0.015***
Misalignment of the roof and floor of incisions (%)			
Superotemporal	1 (4.8)	8 (36.4)	**0.021**†
Superonasal	0 (0)	4 (18.2)	0.108†
Inferotemporal	0 (0)	1 (4.5)	1.000†
Local ciliochoroidal detachment (%)			
Superotemporal	2 (9.5)	4 (18.2)	0.664†
Superonasal	0 (0)	1 (4.5)	1.000†
Inferotemporal	0 (0)	0 (0)	–
Vitreous incarceration (%)			
Superotemporal	1 (4.8)	2 (9.1)	1.000†
Superonasal	1 (4.8)	6 (27.3)	0.095†
Inferotemporal	1 (4.8)	1 (4.5)	1.000†
Incision gaping (%)			
Superotemporal			
External gaping	0 (0)	8 (36.4)	**0.004**†
Internal gaping	1 (4.8)	11 (50)	**0.002**†
Superonasal			
External gaping	0 (0)	4 (18.2)	0.108†
Internal gaping	1 (4.8)	9 (40.9)	**0.009**†
Inferotemporal			
External gaping	0 (0)	3 (13.6)	0.233†
Internal gaping	0 (0)	2 (9.1)	0.488†

SD = standard deviation.
The values in bold indicate statistical significance ($p < 0.05$).
* Student t-test.
† Fisher exact test.

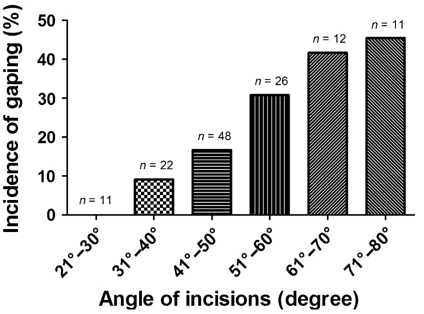

Fig. 3. The incidence of incision gaping in relation to incision angle (n = 129). 'n' indicates the number of sclerotomies. The difference between the six groups is significant (chi-square test; $p = 0.025$). The proportion of gaping increases as the incision angle increases. The more vertical the incision angle, the higher the proportion of gaping.

Discussion

It is currently accepted that compromised wound integrity is an important factor contributing to postoperative leakage in sutureless vitrectomy (Lakhanpal et al. 2005; Shimada et al. 2006; Chen et al. 2010; Lin et al. 2011). Two studies have reported that non-macular, complex or long surgeries have a higher rate of postoperative hypotony than macular or short surgeries (Woo et al. 2009; Lin et al. 2011). However, there are no studies comparing the *in vivo* sclerotomy architecture between macular and non-macular surgeries and its influence in clinical outcomes, especially the postoperative IOP variation.

To our knowledge, our report is the first to compare the OCT features of sutureless transconjunctival 23-G sclerotomies in macular and non-macular surgeries. We found that wound architecture in the early postoperative period was most remodelled in the non-macular surgery group in comparison with the macular surgery group. Further, patients who underwent non-macular surgery exhibited a significant postoperative IOP decrease in comparison with patients who underwent macular surgery. However, the incidence of vitreous incarceration and local ciliochoridal detachment was not statistically different between the two groups of surgery.

In the present study, we used the anterior segment module adapted to the Spectralis SD-OCT device to evaluate the architecture of macular and non-macular surgery wounds. The

Table 4. Intraocular pressure (IOP) before and after surgery in macular and non-macular groups.

Period	Macular surgery ($n = 21$)	Nonmacular surgery ($n = 22$)	p-value
IOP (mean ± SD, mmHg)			
Preoperative	14.24 (3.10)	15.09 (2.58)	0.331*
One day after surgery	14.38 (3.14)	12.18 (3.25)	**0.029***
One week after surgery	14.86 (2.63)	14.09 (2.49)	0.332*
One month after surgery	14.67 (3.31)	14.95 (2.40)	0.745*
Postoperative IOP variation (in comparison with preoperative IOP, mmHg)			
One day after surgery	+0.14	−2.91	**<0.001***
One week after surgery	+0.60	−1.00	**0.006***
One month after surgery	+0.43	−0.14	0.218*

* Student *t*-test. The values in bold indicate statistical significance ($p < 0.05$).

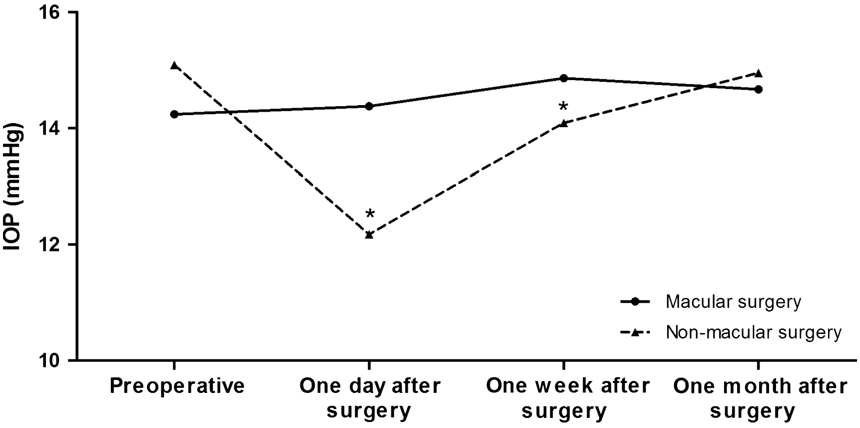

Fig. 4. Mean intraocular pressure (IOP) before and after vitrectomy in the macular and non-macular groups. Preoperative IOP (mmHg) was compared with IOP 1 day, 1 week and 1 month after surgery in each group. *A significant difference between preoperative IOP and postoperative IOP ($p < 0.005$, Paired-samples *t*-test).

SD-OCT used herein has a high-speed image acquisition of 40 000 A-scans per second. Moreover, Spectralis SD-OCT is the only system using Tru-Track technology, which tracks eye micro-movements and maintains the position of the scan in the same place during imaging. The system of real-time averaging of the images allows noise reduction, improves resolution and smoothes the pixilated images. Thus, Spectralis SD-OCT provides better image quality than the Visante OCT (Carl Zeiss Meditec, Dublin, CA, USA). It provides easier detection of scleral incisions and better image interpretation. However, the Spectralis SD-OCT, originally designed for the exploration of the retina, has a shorter wavelength than the Visante OCT (820 nm versus 1310 nm), and its penetration through tissues is lower (Radhakrishnan et al. 2005; Taban et al. 2009); nevertheless, this did not prevent us from obtaining high-quality images.

Spectral-domain OCT showed differences in incision morphology between macular and non-macular surgery groups. In the present series, each incision was created with a 30° angle by two experienced surgeons following the same protocol in an attempt to reduce the effects of wound creation on IOP variation. Despite these precautions for incision construction, the incision angles were more vertical in the non-macular surgery group in comparison with the macular surgery group and there was more internal and external gaping, and more misalignments of the roof and floor of the incisions in the non-macular surgery group. This could be explained by a 'time effect'. Surgical duration and extensive manipulations induce tissue fatigue and stretching. Thus, the longer the surgical duration, the more vertical the incision angle. Scleral tissue therefore progressively becomes distorted, due to its inflexibility in structure and rigidity, leading to a straight angle and wound gaping. These findings are consistent with those of Lin et al., who found that surgical duration is a risk factor for wound leakage even with angled incisions (Lin et al. 2011).

In addition to the 'time effect', non-macular surgery requires substantial trocar rotations to access the extreme retinal periphery, while macular surgery only requires working in the posterior pole with fewer trocar manipulations. Extensive manipulations induce mechanical stretching and enlargement of the sclerotomy site, leading to leakage and postoperative hypotony. That is what we can call the 'hand effect', which is greater in non-macular surgery than in macular surgery. This 'hand effect' could also explain the architectural modifications of the most solicited incisions during surgery. Consequently, superotemporal and superonasal sclerotomies were associated with more architectural remodelling than inferotemporal sclerotomy. We found significantly more incision gaping in superotemporal and superonasal quadrants than in the inferotemporal quadrant, in both the macular and non-macular surgery groups. Similarly, the incision angle was more vertical in the superotemporal and superonasal quadrants than in inferotemporal quadrant in the two surgery groups. Mechanical constraints induced by the manipulation of instruments, particularly in non-macular surgery, are greater in active ports than in the infusion port, which could modify the initial incision architecture and make them straighter and more open.

Intraocular pressure remained stable in the postoperative period in the macular surgery group, whereas a transient initial hypotony was noted in the non-macular surgery group. One day after surgery, the mean IOP increased 0.14 mmHg in the macular surgery group, while it decreased 2.91 mmHg in the non-macular surgery group; this difference was statistically significant. The difference in the postoperative IOP change between the two groups could be explained by the difference in incision remodelling between these two surgery groups.

These findings are similar to those observed after sutureless clear corneal incisions. Our team had studied corneal incisions using anterior segment

OCT and found that straight and remodelled corneal incisions were associated with an increased risk of leakage, hypotony and infection (Dupont-Monod et al. 2009). As for corneal incisions in cataract surgery, an oblique sclerotomy can reduce the risk of endophthalmitis because of the valve phenomenon, the internal lip press against the outer lip through IOP, thereby helping the closure of the wound and reducing the risk of leakage, hypotony and infection. This affixing of the banks increases as the IOP increases.

The incidence of intraoperative suture placement for leaking sclerotomy in this study was 2.3% (3/132 sclerotomies), which is comparable with the 0–15% cited in the literature (Fine et al. 2007; Gupta et al. 2008; Hu et al. 2009; Teixeira et al. 2009; Woo et al. 2009; Singh et al. 2010; Ho et al. 2011). The patient who needed sclerectomy suturing underwent complex and long non-macular surgery. He was excluded from analysis because the OCT features in sutured wounds could be more difficult to interpret.

The incidence of vitreous incarceration varies from 1.9% to 72% according to different reports (Bhende et al. 2000; López-Guajardo et al. 2007; Shimada et al. 2008; Chen et al. 2010). It has been reported that these variances may be due to the different surgical techniques adopted. In the present series, vitreous incarceration was detected with SD-OCT in 9.3% of the 23-gauge sclerotomies. The incidence was not statistically different between the two surgery groups. This low incidence could be explained in macular surgery by the good wound apposition and in non-macular surgery by the vitreous shaving around sclerotomy sites which already proved to significantly decrease vitreous incarceration in sutureless vitrectomies (Sabti et al. 2001; Singh et al. 2008; Chen et al. 2010). Recently, a new Miyake-Apple view has been used in porcine eye to observe the inner surface of the sclerotomy during microincision vitrectomy surgery. This new approach will help better evaluate vitreous incarceration (Inoue et al. 2011).

The difference in mean conjunctival thickness between the two groups of surgery could be explained by most important leakage in non-macular surgery resulting in conjunctival oedema and infiltration.

The present study had a number of potential limitations. First, although this study was prospective, the patients were not randomly assigned, as the choice of surgery was dictated by the disease. Second, this study investigated a small number of patients. Third, the OCT examination was not repeated so as to evaluate the differences of scleral wound closure in the two groups over time.

In conclusion, the experimental module of the anterior segment of Spectralis SD-OCT is a valuable tool in evaluating the wound architecture of sutureless vitrectomy incisions. It provided clear images of 23-G sutureless vitrectomy wounds and revealed that non-macular and long surgery had straighter incisions with more gaping than macular and short surgery. These findings contribute to a better understanding of scleral wound distortion during surgery and show that the wound architecture at the end of surgery results from a dynamic process that is not limited to the moment of incision construction. This process is determined by two important factors, the 'time effect' and the 'hand effect', which tend to make incisions increasingly opened and stretched the longer surgery lasts. This hypothesis may explain why longer surgical duration and non-macular surgery seem to increase the risk of wound leakage even when the trocars are initially obliquely inserted in the sclera. Indeed, non-macular surgery was associated with a significant postoperative IOP decrease in comparison with macular surgery. We believe that, as has been advanced for cornea (Roberts 2000), sclera is not a piece of plastic. We emphasize the need for rigorous construction of oblique incisions and advocate meticulous examination of incisions at the end of surgery, especially in conditions associated with increased risk of leakage such as long, complex and non-macular surgery. Surgeons should not hesitate to suture the sclerotomy if leakage is present. Further prospective studies with larger series and longer follow-up are needed to evaluate the differences in the wound closure process in these two groups.

Acknowledgements

No conflicting relationship exists for any author.

References

Androudi S, Praidou A, Symeonidis C, Tsironi E, Iaccheri B, Fiore T, Tsinopoulos I & Brazitikos P (2012): Safety and efficacy of small incision, sutureless pars plana vitrectomy for patients with posterior segment complications secondary to uveitis. Acta Ophthalmol **90**: e409–410.

Awan MA, Lyall DA & Koshy ZR (2012): A novel technique of tangential, circumferential, scleral tunnel in 20-gauge transconjunctival sutureless vitrectomy: optical coherence tomography-aided analysis of wound integrity and clinical outcome. Br J Ophthalmol **96**: 193–196.

Bhende M, Agraharam SG, Gopal L et al. (2000): Ultrasound biomicroscopy of sclerotomy sites after pars plana vitrectomy for diabetic vitreous hemorrhage. Ophthalmology **107**: 1729–1736.

Chen E (2007): 25-Gauge transconjunctival sutureless vitrectomy. Curr Opin Ophthalmol **18**: 188–193.

Chen D, Lian Y, Cui L, Lu F, Ke Z & Song Z (2010): Sutureless vitrectomy incision architecture in the immediate postoperative period evaluated *in vivo* using optical coherence tomography. Ophthalmology **117**: 2003–2009.

Dupont-Monod S, Labbé A, Fayol N, Chassignol A, Bourges JL & Baudouin C (2009): *In vivo* architectural analysis of clear corneal incisions using anterior segment optical coherence tomography. J Cataract Refract Surg **35**: 444–450.

Fine HF, Iranmanesh R, Iturralde D & Spaide RF (2007): Outcomes of 77 consecutive cases of 23-gauge transconjunctival vitrectomy surgery for posterior segment disease. Ophthalmology **114**: 1197–1200.

Framme C, Klotz S, Wolf-Schnurrbusch UE, Wiedemann P & Wolf S (2011): Intraocular pressure changes following 20G pars-plana vitrectomy. Acta Ophthalmol [Epub ahead of print].

Gupta OP, Ho AC, Kaiser PK et al. (2008): Short-term outcomes of 23-gauge pars plana vitrectomy. Am J Ophthalmol **146**: 193–197.

Guthoff R, Riederle H, Meinhardt B & Goebel W (2010): Subclinical choroidal detachment at sclerotomy sites after 23-gauge vitrectomy: analysis by anterior segment optical coherence tomography. Ophthalmologica **224**: 301–307.

Ho LY, Garretson BR, Ranchod TM et al. (2011): Study of intraocular pressure after 23-gauge and 25-gauge pars plana vitrectomy randomized to fluid versus air fill. Retina **31**: 1109–1117.

Hu AY, Bourges JL, Shah SP, Gupta A, Gonzales CR, Oliver SC & Schwartz SD (2009): Endophthalmitis after pars plana vitrectomy a 20- and 25-gauge comparison. Ophthalmology **116**: 1360–1365.

Inoue M, Ota I, Taniuchi S, Nagamoto T, Miyake K & Hirakata A (2011): Miyake-Apple view of inner side of sclerotomy during microincision vitrectomy surgery. Acta Ophthalmol **89**: e412–e416.

Lakhanpal RR, Humayun MS, de Juan E Jr et al. (2005): Outcomes of 140 consecutive cases of 25-gauge transconjunctival surgery for posterior segment disease. Ophthalmology **112**: 817–824.

Lin AL, Ghate DA, Robertson ZM, O'Sullivan PS, May WL & Chen CJ (2011): Factors affecting wound leakage in 23-gauge sutureless pars plana vitrectomy. Retina **31**: 1101–1108.

López-Guajardo L, Vleming-Pinilla E, Pareja-Esteban J & Teus-Guezala MA (2007): Ultrasound biomicroscopy study of direct and oblique 25-gauge vitrectomy sclerotomies. Am J Ophthalmol **143**: 881–883.

Okamoto F, Okamoto C, Sakata N, Hiratsuka K, Yamane N, Hiraoka T, Kaji Y & Oshika T (2007): Changes in corneal topography after 25-gauge transconjunctival sutureless vitrectomy versus after 20-gauge standard vitrectomy. Ophthalmology **114**: 2138–2141.

Radhakrishnan S, Goldsmith J, Huang D, Westphal V, Dueker DK, Rollins AM, Izatt JA & Smith SD (2005): Comparison of optical coherence tomography and ultrasound biomicroscopy for detection of narrow anterior chamber angles. Arch Ophthalmol **123**: 1053–1059.

Rizzo S, Genovesi-Ebert F, Murri S, Belting C, Vento A, Cresti F & Manca ML (2006): 25-gauge, sutureless vitrectomy and standard 20-gauge pars plana vitrectomy in idiopathic epiretinal membrane surgery: a comparative pilot study. Graefes Arch Clin Exp Ophthalmol **244**: 472–479.

Roberts C (2000): The cornea is not a piece of plastic. J Refract Surg **16**: 407–413.

Romero P, Salvat M, Almena M, Baget M & Méndez I (2006): Experience with 25-gauge transconjunctival vitrectomy compared to a 20-gauge system. Analysis of 132 cases [in French]. J Fr Ophtalmol **29**: 1025–1032.

Sabti K, Kapusta M, Mansour M, Overbury O & Chow D (2001): Ultrasound biomicroscopy of sclerotomy sites: the effect of vitreous shaving around sclerotomy sites during pars plana vitrectomy. Retina **21**: 464–468.

Sandali O, El Sanharawi M, Lecuen N et al. (2011): 25-, 23-, and 20-gauge vitrectomy in epiretinal membrane surgery: a comparative study of 553 cases. Graefes Arch Clin Exp Ophthalmol **249**: 1811–1819.

Sawada T, Kakinoki M, Sawada O, Kawamura H & Ohji M (2011): Closure of sclerotomies after 25- and 23-gauge transconjunctival sutureless pars plana vitrectomy evaluated by optical coherence tomography. Ophthalmic Res **45**: 122–128.

Shimada H, Nakashizuka H, Mori R, Mizutani Y & Hattori T (2006): 25-gauge scleral tunnel transconjunctival vitrectomy. Am J Ophthalmol **142**: 871–873.

Shimada H, Nakashizuka H, Hattori T, Mori R, Mizutani Y & Yuzawa M (2008): Vitreous prolapse through the scleral wound in 25-gauge transconjunctival vitrectomy. Eur J Ophthalmol **18**: 659–662.

Singh A, Chen JA & Stewart JM (2008): Ocular surface fluid contamination of sutureless 25-gauge vitrectomy incisions. Retina **28**: 553–557.

Singh CN, Iezzi R & Mahmoud TH (2010): Intraocular pressure instability after 23-gauge vitrectomy. Retina **30**: 629–634.

Taban M, Sharma S, Ventura AA & Kaiser PK (2009): Evaluation of wound closure in oblique 23-gauge sutureless sclerotomies with Visante optical coherence tomography. Am J Ophthalmol **147**: 101–107.

Teixeira A, Allemann N, Yamada AC, Uno F, Maia A & Bonomo PP (2009): Ultrasound biomicroscopy in recently postoperative 23-gauge transconjunctival vitrectomy sutureless self-sealing sclerotomy. Retina **29**: 1305–1309.

Woo SJ, Park KH, Hwang JM, Kim JH, Yu YS & Chung H (2009): Risk factors associated with sclerotomy leakage and postoperative hypotony after 23-gauge transconjunctival sutureless vitrectomy. Retina **29**: 456–463.

Yamane S, Kadonosono K, Inoue M, Kobayashi S, Watanabe Y & Arakawa A (2011): Effect of intravitreal gas tamponade for sutureless vitrectomy wounds: three-dimensional corneal and anterior segment optical coherence tomography study. Retina **31**: 702–706.

Received on February 22nd, 2012.
Accepted on September 15th 2012.

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