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Case Series

Vitreous Wiping, a new technique for removal of vitreous cortex remnants during vitrectomy

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ABSTRACT.

Purpose: **Unremoved vitreoschisis-induced vitreous cortex remnants (VCR) are associated with macular pathology. When present on the retinal periphery, they may play a role in proliferative vitreoretinopathy and retinal detachment after vitrectomy. Existing instruments for their removal involve substantial risk of iatrogenic retinal damage. Purpose of this study was to evaluate the use of a new technique, Vitreous Wiping, for removal of VCR during vitrectomy.**

Methods: **Proof-of-concept case series of six eyes (six patients) treated with vitrectomy for various pathologies (macula-on and macula-off retinal detachment, macular hole, macular pucker and vitreous floaters). Vitreous cortex remnants on the surface of the retina were visualized with triamcinolone and removed by Vitreous Wiping with a rectangular piece of polyvinyl alcohol (PVA) held with intra-ocular forceps. Visual acuity and clinical course were assessed during a follow-up of 6 months. All eyes underwent postoperative macular optical coherence tomography. Eyes without preoperative macular pathology, underwent retinal sensitivity testing and eyes without paracentral pathology underwent visual field analysis.**

Results: **Vitreous cortex remnants could be removed completely in all eyes. There were no intra- or postoperative complications. We observed that PVA is soft like a sponge and vitreous sticks to it, making Vitreous Wiping easier and safer, compared to alternative instruments. Visual acuity improved in all eyes. Microperimetry and visual field analysis revealed no abnormalities related to Vitreous Wiping.**

Conclusion: **Vitreoschisis-induced VCR can be removed effectively and safely from the retinal surface by Vitreous Wiping. Larger studies are needed to confirm this promising finding and its potential impact.**

Key words: proliferative vitreoretinopahty – redetachment – vitreoschisis – vitreous cortex remnants – vitreous wipe – Vitreous Wiping

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Introduction

Vitreoschisis is an anomalous type of (spontaneous or iatrogenic) posterior vitreous detachment (PVD) in which the posterior vitreous cortex is split (Sebag 2008). Due to its lamellar structure, the outermost layer of the vitreous cortex may remain attached to the retina. This layer can exert traction on the retina.

Vitreoschisis is present in 53% of patients with macular holes (Sebag 2008) and 80% of patients with macular pucker (Yamashita et al. 2008). Also, it is often observed in highly myopic patients undergoing retinal detachment (RD) repair (Liu et al. 2011). These findings are in accordance with our own surgical experience: namely, that vitreoschisis-induced vitreous cortex remnants (VCR) are present in many cases of primary RD, not only highly myopic eyes. In addition, VCR on the surface of the retina has been involved in most cases of redetachment that we have encountered. Therefore, we suspect that unremoved VCR from the retinal surface lead to an increased risk of redetachment. Especially in highly myopic eyes, the redetachment rate has been reported to be as high as 27% (Dugas et al. 2013). The role of vitreoschisis in this has not yet been investigated. Removing VCR from the entire retinal surface contributed to the success of the surgical treatment of retinal vascular tumours (Van Overdam et al. 2017).

Unless well visualized with triamcinolone, which is not commonly used during vitrectomy, VCR on the retinal surface are impossible to see and therefore almost impossible to remove. Even when visualized, the removal of these remnants with end-gripping forceps, or with other instruments that are not purpose-built, is difficult. The underlying retina can be easily damaged. In addition, the procedure is very time-consuming. Moreover, many surgeons have either the impression that

not removing VCR has no serious implications or that removal carries more risks than benefits. For reasons such as these, vitreoschisis is not routinely diagnosed during vitrectomy nor are VCR routinely removed.

We developed a new technique, Vitreous Wiping, by which VCR can be removed from the surface of both attached and detached retina in a safe, comprehensive and efficient manner. The goal of the study was to use the technique of Vitreous Wiping during vitrectomy for various indications in a series of patients.

Methods

During a 2-month period, the first author asked patients before surgery for permission to use a new technique for removal of VCR if and when it was discovered intra-operatively. Inclusion criteria for this study were: informed consent, presence of VCR confirmed intra-operatively by triamcinolone and the presence of one of the following surgical indications: primary rhegmatogenous RD (macula-on or macula-off), macular hole, macular pucker and vitreous floaters. Exclusion criteria were: presence of proliferative vitreoretinopathy (PVR), previous vitreoretinal surgery and use of silicon oil tamponade. We prospectively included six patients (six eyes).

The preoperative characteristics of study patients are given in Table 1. All patients underwent a detailed ophthalmic history and examination including measurement of Snellen best-corrected visual acuity (BCVA), slit-lamp biomicroscopy, dilated fundal exam and a macular volume measurement (macula 3D scan) by optical coherence tomography (OCT; Canon OCT-HS100, Canon, Middlesex, UK). Vitrectomy was carried out by the first author (KvO), with the Stellaris PC (Bausch & Lomb, Irvine, CA, USA) and 23-gauge set-up. Vitreous visualization was enhanced with triamcinolone acetonide (Kenacort-A 40, Bristol-Myers Squibb Srl, Anagni, Italy). The preservatives were first removed from the suspension. The final concentration of triamcinolone was 20 mg/ml. After standard vitrectomy, the presence and extent of VCR on the surface of the retina, was confirmed by readministering triamcinolone in the vitreous cavity and directing it towards the retinal surface,

Table 1. Preoperative, intra-operative and postoperative details of study patients.

Patients	Age (years)	Sex	Eye	Diagnosis	Lens status	Pre-op BCVA	Treatment	Area with VCR	Removal of VCR	Intra-op Complic	Post-op Complic	Post-op MP	Post-op HFA 30-2	Post-op BCVA	Follow-up (months)
1	72	M	LE	Macular pucker	Pseudo phakic	0.05	Vit, ERM, ILM, laser, air	2Q	Complete	None	None	–	SS	0.3	6
2	65	F	RE	Macular hole	Phakic	0.3	Vit, ILM, laser, C_3F_8	Entire retina	Complete	None	Cataract	–	HH	0.7	6
3	65	F	LE	Vitreous floaters	Pseudo phakic	0.7	Vit, laser, air	Entire retina	Complete	None	None	NS	NS	1.0	6
4	74	M	RE	Mac on RD, 2Q	Pseudo phakic	0.7	Vit, PFCL, laser, C_3F_8	Entire retina	Complete	None	None	NS	–	0.9	6
5	72	M	LE	Mac off RD, total	Pseudo phakic	0.2	Vit, ERM, ILM, PFCL, laser, C_3F_8	Entire retina	Complete	None	None	–	–	0.9	6
6	60	M	LE	Mac off RD, 2Q	Pseudo phakic	HM	Vit, ILM, PFCL, laser, C_3F_8	Entire retina	Complete	None	None	–	–	0.4	6

Vitreous Wiping was used to remove vitreoschisis-induced VCR, during Vit for various indications.
BCVA = best-corrected visual acuity, C_3F_8 = 15% octafluoropropane gas, Complic = complications, ERM = epiretinal membrane peeling, F = female, HFA = Humphrey field analyser, HH = homonymous hemianopia (likely preexisting), HM = hand movement, ILM = internal limiting membrane peeling, Intra-op = intra-operative, laser = 360° of laser, LE = left, M = male, Mac = macula, MP = microperimetry, NS = no significant wiping-related changes, Pat = patient, PFCL = use of perfluorocarbon liquid, Post-op = postoperative, Pre-op = preoperative, Q = quadrant, RD = retinal detachment, RE = right eye, SS = small scotoma (10 × 10° in size, temporal between 10 and 20° from fixation, just above the horizontal meridian, not in an area treated by wiping but at the edge of the ILM peeling area), VCR = vitreous cortex remnants, Vit = vitrectomy.

covering all quadrants methodically. The triamcinolone particles adhered to VCR and could not be removed by flushing the retinal surface with a flute cannula or with the backflush function of the cutter. This demonstrated to us that they were not just resting as a sediment on the retinal surface but were in fact attached to VCR.

Vitreous Wiping

Vitreous Wiping was performed with a piece of polyvinyl alcohol (PVA) held in place by end-gripping forceps. The piece of dry PVA came from a sheet of the Eyetec™ PVA Instrument Wipe (Network Medical Products, North Yorkshire, UK). The Eyetec PVA instrument Wipe is specifically developed to effectively clean and extend the life of delicate microsurgical instruments (https://www.networkmedical.co.uk/ophthalmic/product-type/pva-cellulose-products/eyetec-pva-instrument-wipe) and is available during all our standard vitreoretinal procedures. Cutting a piece of PVA from a larger piece does not cause microscopic fragmentation (Poole et al. 2002), so the size of the wipe could be adjusted safely.

With scissors, the surgeon cuts a small rectangular piece of PVA from the Eyetec™ PVA Instrument Wipe of about $3 \times 2 \times 1$ mm. The piece of PVA was held with intra-ocular forceps and introduced into the eye through an existing sclerotomy after removing one of the valved trocars and opening the conjunctiva over the sclerotomy. Fashioning of the Vitreous Wipe can be seen in the Video S1. Vitreous cortex remnants were removed both from the surface of the macula and from the retinal midperiphery, when present, by gently moving the Vitreous Wipe over the retinal surface. All operations were recorded for validation purposes. Specifically, the extent, thickness of the VCR and whether they formed a continuous membrane on the retinal surface, were recorded. After their removal, triamcinolone was readministered to check for persistent remnants. The goal was to remove all of the remnants up to the vitreous base.

In the two patients with presumed normal preoperative macular function, patient 3 (vitreous floaters) and patient 4 (macula-on RD), the internal limiting membrane (ILM) was not peeled during surgery. The ILM was peeled in the other four patients. The intra-operative details of all surgeries are given in Table 1.

Follow-up was 6 months. At last follow-up, all patients underwent measurement of Snellen BCVA, slit-lamp biomicroscopy, including dilated fundal exam and a macular volume measurement (macula 3D scan) by OCT (Canon OCT-HS100). To investigate possible toxicity or mechanical damage by Vitreous Wiping over the central macula, microperimetry (Nidek MP1 Microperimeter, Nidek, Fremont, CA, USA) was carried out 3 months postoperatively, in patients with presumed normal preoperative macular function (patient 3 with vitreous floaters and patient 4 with macula-on RD). Retinal sensitivity of the central 4° to fixation was tested at 44 points with a Goldman III stimulus size, 200 ms stimulus duration and a 4–2 strategy on a 10 cd/m^2 background. The stimulus level ranged between 0 and 20 decibel (dB). In addition, to investigate possible toxicity or mechanical damage of the Vitreous Wipe on the paracentral retina, static visual field analysis (Humphries Field Analyzer HF II; Carl Zeiss Meditec AG, Jena, Germany) of the central 30° to fixation, was carried out 3 months postoperatively, in patients with presumed normal preoperative mid-peripheral retinal function (patient 1 with macular pucker, patient 2 with macular hole and patient 3 with vitreous floaters). A central 30-2 threshold test was carried out with a Goldman III white stimulus and a Swedish interactive threshold algorithm-standard strategy on a 31.5 cd/m^2 background.

Results

Visualized VCR were completely removed from the treated surface of the retina in all patients. Figure 1 shows a video still image of each patient.

In patient 1 (macular pucker, Fig. 1A), only the temporal part of the retinal surface was covered by VCR. After ILM peeling was performed, VCR could be removed effectively over the affected area as membranes by Vitreous Wiping.

In patient 2 (macular hole, Figs 1B and 2), the entire retinal surface, from posterior pole to vitreous base, was covered by VCR. It was successfully treated by Vitreous Wiping after ILM peeling. Vitreous cortex remnants could be removed as large membranes.

In patient 3 (vitreous floaters, Fig. 1C), the entire retina was covered by VCR. No ILM peeling was performed. Vitreous Wiping was successfully performed over the macula to remove macular VCR and over the retinal periphery where VCR could be removed as large membranes.

In patient 4 (macula-on two quadrant RD, Fig. 1D), the entire retina was covered by VCR. No ILM peeling was performed. Vitreous cortex remnants was successfully removed in small pieces by Vitreous Wiping from the macula and the peripheral retina. Perfluorocarbon (PFCL) was used to stabilize the detached peripheral retina and to provide countertraction against the movements of the Vitreous Wipe over the peripheral retina.

In patient 5 (macula-off total RD, Fig. 1E), the entire retina was covered by VCR. After ILM peeling was performed, VCR was successfully removed in small pieces by Vitreous Wiping with the use of PFCL to stabilize the detached peripheral retina.

In patient 6 (macula-off two quadrant RD, Fig. 1F), the entire retina was covered by VCR. Internal limiting membrane peeling was performed and VCR was completely removed by Vitreous Wiping under PFCL as large membranes.

There were no intra-operative complications. Specifically, no mechanical damage was caused to the retina, centrally or peripherally, when Vitreous Wiping was performed over the retinal surface. The intra-operative technique of Vitreous Wiping can be seen in the Video S1.

Postoperative BCVA (Snellen) is shown in Table 1. Best-corrected visual acuity improved in all patients. Patient 1 improved from 0.05 to 0.3; patient 2 from 0.3 to 0.7; patient 3 from 0.7 to 1.0; patient 4 from 0.7 to 0.9; patient 5 from 0.2 to 0.9; and patient 6 from hand movements to 0.4.

Central retinal sensitivity was within normal limits in the two patients that underwent microperimetry. In the three patients who underwent visual field analysis, paracentral retinal sensitivity was normal in the patient with floaters. The patient with macular hole had a right homonymous hemianopia, sparing the central 15° of fixation. The patient with macular pucker had a small round scotoma, about 10° by 10° in size, temporal, between 10 and

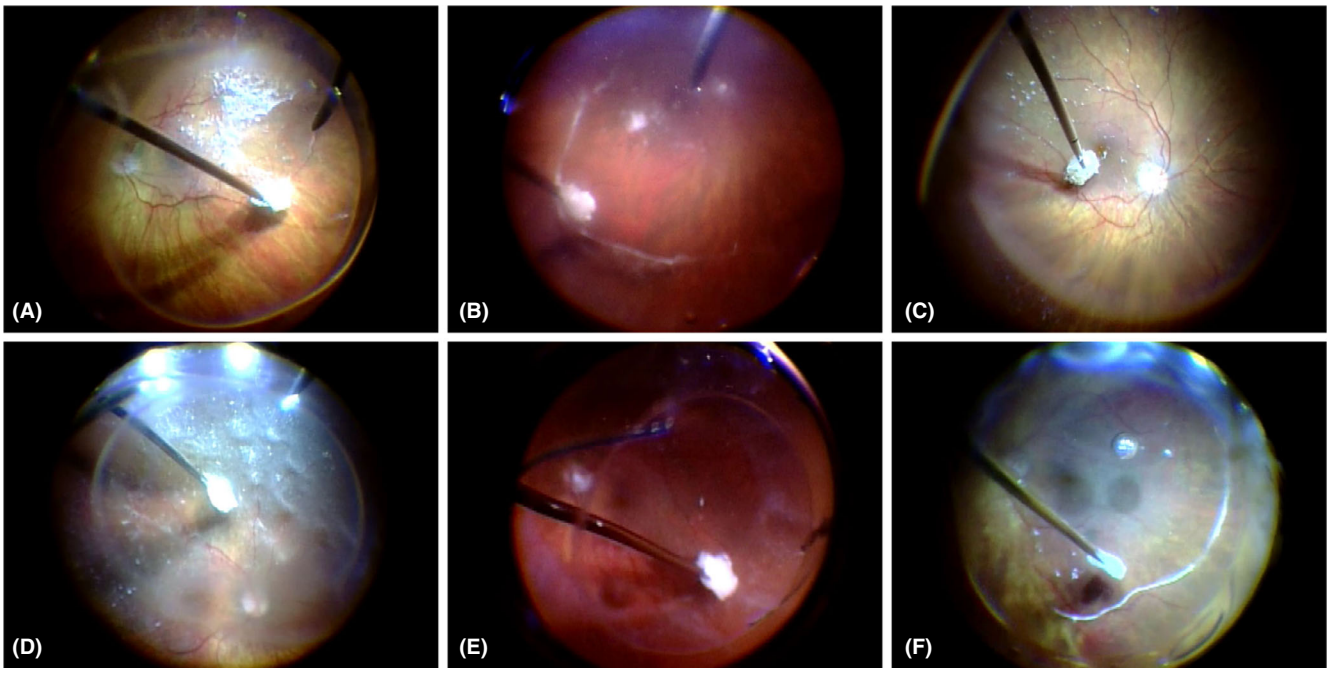

Fig. 1. Video still images of the six study patients (A–F, respectively). Vitreous Wiping was used to remove vitreoschisis-induced vitreous cortex remnants (VCR). (A: patient 1; macular pucker) Only part of the retinal surface was covered by VCR in patient 1. (B: patient 2; macular hole) VCR removed as large membranes. (C: patient 3; vitreous floaters) Vitreous Wiping performed over the macula to remove macular VCR. (D: patient 4; macula-on retinal detachment, RD) Vitreous cortex remnants removed in small pieces, not as membranes. (E: patient 5; macula-off RD) Perfluorocarbon liquid (PFCL) was used to stabilize the detached peripheral retina and provide countertraction against the movements of the Vitreous Wipe. (F: patient 6; macula-off RD) Vitreous cortex remnants completely removed under PFCL as membranes.

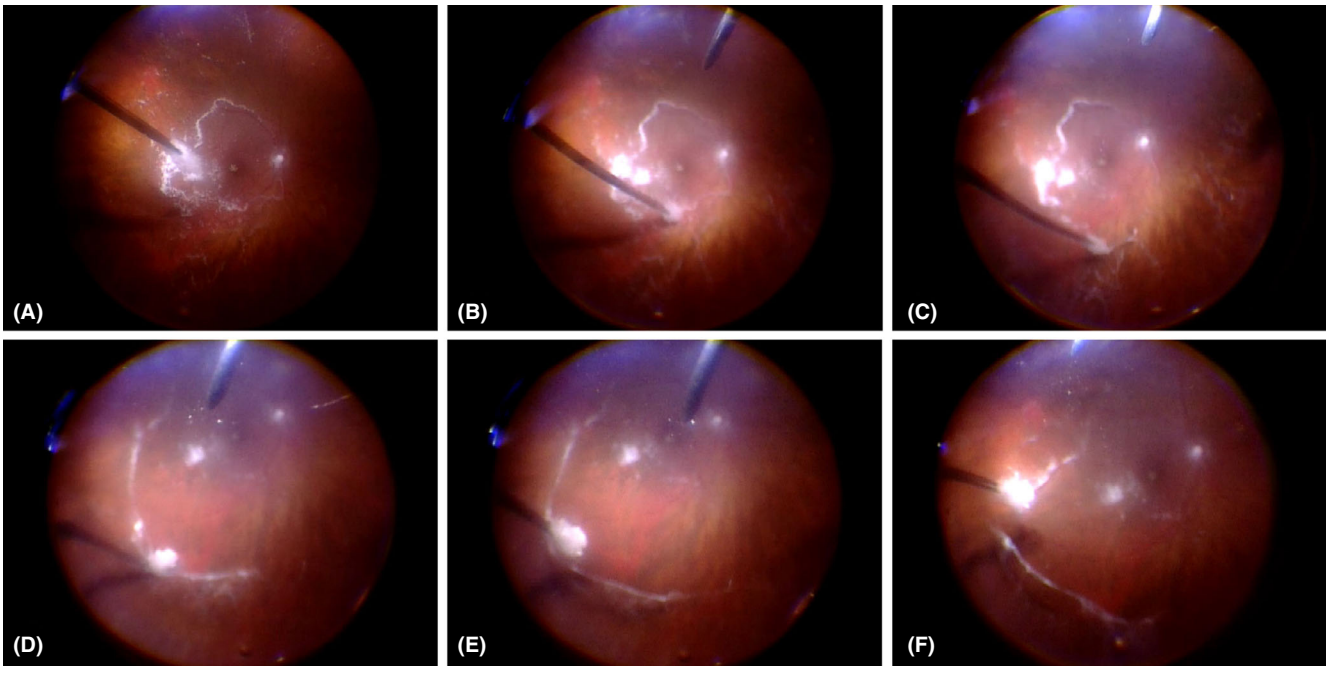

Figure 2. Vitreous Wiping performed after vitrectomy, internal limiting membrane (ILM) peeling and staining with triamcinolone acetonide (TA) in patient 2. (A) The vitreoschisis-induced vitreous cortex remnants (VCR) covering the retinal periphery are stained by TA and are most visible at the edge of the area of ILM peeling. VCR has already been removed from the posterior pole by ILM peeling. (B–F) The Vitreous Wipe is gently passed over the surface of the retina, wiping away the layer of VCR towards the periphery, ultimately removing it from the retinal surface without retinal damage.

20° from fixation and just above the horizontal meridian, with a maximum pattern deviation of −20. The phakic patient in this series had developed cataract at final follow-up.

Discussion

We used a new technique, Vitreous Wiping, for the removal of VCR resulting from vitreoschisis, from the macular, paracentral and peripheral retina, in a series of patients undergoing vitrectomy for various indications. The goal of the study was to examine the safety, ease of use and effectiveness of Vitreous Wiping with a piece of PVA.

Vitreous Wiping effectively and completely removed vitreous cortex from the retinal surface (macula, paracentral and peripheral retina) in all patients. The persistence or complete removal of vitreous cortex was confirmed by the repeat administration of triamcinolone on the surface of the retina after Vitreous Wiping. The elastic sponge-like nature of Eyetec™ PVA enabled easy following the position of the retina under different angles. Vitreous Wiping was effective over both attached and detached retina. Admittedly, Vitreous Wiping is easier in partially rather than completely detached retina, as the area of attached retina provides a point of counter-traction away from which the wiping movements can be directed. Perfluorocarbon liquid could be used to provide this counter-traction and Vitreous Wiping was also effective under PFCL.

The Eyetec™ PVA used for Vitreous Wiping showed high affinity for the VCR. Polyvinyl alcohol is known to adhere to prolapsed vitreous strands and has been used for many years for sponge or dry vitrectomy in cases of traumatic vitreous prolapse or vitreous prolapse during phacoemulsification (Berger et al. 1980; Akura et al. 2001). Alternative instruments do not have the same affinity for the vitreous as PVA. The respective structural characteristic of PVA and vitreous ensure that PVA adheres so well to vitreous: the PVA architecture, with its interconnected pores and fast wicking and the vitreous architecture, with its fine network of mixed composition collagen fibrils (Sebag et al. 2014). This high mutual affinity resulted in much faster and safer removal of VCR compared to any of the alternative instruments the authors have tried so far, such as the vitreous cutter, end-gripping forceps, silicone brush, tissue manipulator or diamond-dusted membrane scraper.

Polyvinyl alcohol sheets come with different pore sizes. The pore size of Eyetec™ PVA is 130 μm. It is possible that the affinity of PVA for vitreous is dependent on the size of the interconnected pores. We have not tried any PVA sheets with different pore sizes. Therefore, the optimal pore size for maximum vitreous affinity has not yet been determined. In addition, the piece of wipe was fashioned by the surgeon from a larger PVA sheet. The effectiveness of wiping also appears to depend on the size of the rectangular PVA piece. This varied slightly between patients in this study (see Video S1). The width of the PVA piece was constant (it corresponded to the thickness of the Eyetec™ PVA sheet from which it was fashioned, while the length and the thickness of the PVA piece were determined by the surgeon. In patient 1, the wipe was smaller than in the rest of the patients and in patient 5, it was shorter than the rest of the patients. We fashioned a second wipe, of better size and shape, in both operations. The optimal size of wipe was not yet been determined, but it appears from this study, that a $3 \times 2 \times 1$-mm-size wipe is most effective in removing vitreous from the retinal surface.

No inadvertent iatrogenic mechanical trauma (retinal tears or holes) was caused by Vitreous Wiping of any area of the retina. We believe that this was achieved by trying not to press the wipe onto the retina, but by gently following the contour of the retina and by the cutting of the wipe, being sufficiently long and wide enough to have enough surface area for effective wiping. In our experience mechanical trauma is not easy to avoid when the alternative instruments mentioned above are used. In addition, a number of reports describe OCT-defined retinal defects after the use of the forceps or a diamond-dusted membrane scraper (Kuhn et al. 1998; Ehlers et al. 2015; Leung et al. 2016;). However, our study only included 6 patients and a larger study is needed to investigate the incidence of iatrogenic retinal defects during Vitreous Wiping.

Polyvinyl alcohol does not leave deposits or residue when in contact with instruments or tissues. Polyvinyl alcohol sponges are used for the intra-operative protection of cornea and conjunctiva (Norn 1981) and in trabeculectomy, to soak the surface of the sclera, from which the trabeculectomy flap will be fashioned, with antifibrotic agents (Khaw et al. 2017). Polyvinyl alcohol sponges are now preferred to the original cellulose sponges used in earlier studies, because they maintain integrity, do not leave fragments behind and are completely lint and fibre-free, compared to cellulose (Poole et al. 2002). In this case series, there were no instances of deposits noted during surgery or on postoperative fundoscopy or imaging, in contrast to reports about alternative instruments for the removal of VCR (Gupta & Goldsmith 2009).

Polyvinyl alcohol is known to be inert, non-toxic and non-carcinogenic. It is used as a viscosity-increasing agent in viscous ophthalmic products, as a lubricant for contact lens solutions, in sustained release oral formulations and in transdermal patches (Kadajji & Betageri 2011). It is used in intravitreal implants such as Retisert (Jaffe et al. 2006; Callanan et al. 2008; Pavesio et al. 2010). To investigate possible toxicity of Vitreous Wiping on the central macula, we carried out microperimetry in two patients with presumed normal preoperative macular function and no ILM peeling. There were no postoperative microperimetry abnormalities in these patients. To investigate possible toxicity of Vitreous Wiping on the paracentral retina, we carried out static visual field analysis in patients with presumed normal preoperative mid-peripheral retinal function. One patient had a previously undiagnosed right homonymous hemianopia which is unlikely to be related to the surgery. One patient had a small temporal paracentral scotoma between 10 and 20° of fixation. Upon analysis of the surgical video the area of scotoma was at the edge of the area of ILM peeling. The area of Vitreous Wiping was more temporal. Therefore, it does not appear to be related to Vitreous Wiping but may be related to the ILM peeling. Also, due to lack of preoperative visual field analysis we cannot rule out the possibility that this scotoma predates the surgery. The retinal sensitivity and visual field results, though limited, give no indication that Vitreous Wiping causes retinal toxicity. However, the lack of preoperative imaging and the

small size of this series are limitations that we acknowledge.

Anomalous PVD is known to lead to macular vitreoschisis, which in turn is involved in the pathophysiology of macular hole and macular pucker formation via the persistence of VCR on the macular surface (Gupta et al. 2011; Schumann et al. 2014; Sebag et al. 2014; Romano et al. 2015). The possible effect of vitreoschisis-induced VCR on the retinal periphery has, to our knowledge, not been investigated to date. A possible reason for this is that repeated applications of triamcinolone in the vitreous cavity during vitrectomy are necessary for the visualization of residual vitreous cortex. Even though the usefulness of triamcinolone as a vitreous staining agent is well known (Yamamoto et al. 2004; Schmidt et al. 2008; Fang et al. 2009), its use in vitrectomy is, at present, not routine. It is our clinical impression that vitreoschisis is more common than previously thought and that not removing vitreous cortex from the retinal surface during vitrectomy for RD increases the risk of redetachment, possibly through the role of VCR as a scaffold for PVR. The importance of a truly complete vitrectomy as well as the currently unacknowledged importance and diagnostic challenge of vitreoschisis have been advocated (Kuhn & Aylward 2014). It remains to be determined when removal of residual vitreous cortex is likely to be of benefit. It is possible that it is not necessary in elective cases, although it may reduce the non-closure or recurrence rate of macular holes or the risk of postoperative RD. In patients with RD it may be useful to remove all VCR in all cases or it might only be necessary to remove it from detached retina, rather than attached retina or only in cases with PVR, coexistent vitreous haemorrhage, large breaks, high myopia or when 360° of preventive peripheral laser is going to be applied.

In our experience, vitreoschisis can lead to residual vitreous cortex membranes over the macula and/or the retinal periphery, or it can lead to VCR in patches. The thickness of the resultant vitreous cortex membrane also varies as a result of the variability of the plane of cleavage during anomalous PVD (Sebag et al. 2014). If the vitreous cortex membrane is thick, it can be removed as a membrane. If thin, it breaks up into pieces during attempted removal and has to be removed piece by piece. Vitreous Wiping successfully removes both thick and thin vitreous cortex membranes as well as patchy vitreous cortex, as demonstrated in the Video S1. We intend to develop the technique into an instrument with an optimal size and shape that will be able to be inserted through a trocar, for ease of use.

Vitreoschisis is currently underdiagnosed during routine vitreoretinal surgery due to the lack of routine vitreous staining. We believe that the potential effects of VCR on the primary success rate of RD surgery and on the development of PVR must be investigated. We propose a new, safe and efficient technique, Vitreous Wiping, for removing VCR from the retinal surface, including the retinal periphery, that has distinct advantages compared to current instruments. Using this technique, we intend to investigate the effect of the removal of VCR on the success rate of vitrectomy for RD.

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Koen van Overdam and Sonia Manning have had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

Supporting Information

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

Video S1. Vitreous Wiping is performed with a piece of polyvinyl alcohol (PVA), of about 3 x 2 x 1 mm in size, cut from a sheet of the Eyetec™ PVA instrument wipe and held in place by end-gripping forceps.