Posterior Scleral Reinforcement for The Treatment of Myopic Foveoschisis

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Abstract

Background: This study aimed to investigate the clinical effectiveness of posterior scleral reinforcement for the treatment of myopic foveoschisis.

Methods: This was a prospective study of 32 eyes from 20 patients with myopic foveoschisis treated with posterior scleral reinforcement using genipin-cross-linked donor sclerae. The length of the scleral strip used for the surgery was designed to be 1.5-times the axial length of the eye, whereas its width was 0.4-times the axial length of the eye. The optical coherence tomography images, spherical equivalent of refractive error, axial length, best corrected visual acuity, electroretinogram findings, and intraocular pressure of the patients were assessed postoperatively.

Results: The mean duration of follow-up was 17.80 ± 8.74 months. The differences between the spherical equivalent of refractive error, best corrected visual acuity, axial length, and electroretinogram findings recorded preoperatively and those measured postoperatively were statistically significant ($p \leq 0.05$). The final reduction in axial length was 1.64 ± 0.85 mm. At the end of the follow-up, optical coherence tomography showed essential foveal reattachment in 30 eyes (93.75%), partial reattachment in two eyes (6.25%), and closure of macular holes in seven eyes (77.78%). No retinal detachment, vitreous haemorrhage, or other serious complications occurred following the surgery.

Conclusions: Posterior scleral reinforcement with genipin-cross-linked sclera showed safe and effective outcomes for the treatment of myopic foveoschisis during a follow-up period of at least one year

Trial registration: ChiCTR1800020012

Background

Myopic foveoschisis (MFS) is one of the most common complications of pathological myopia and was first described by Takano and Kishi in 1999¹. MFS is a split or break between the inner and outer layers of the retinal neuroepithelium and is a major cause of decreased vision in patients with myopia².

A variety of surgical options are currently available for the treatment of MFS³. These include intraocular surgeries—pars plana vitrectomy (PPV) combined with silicone oil or gas tamponade⁴ with or without internal limiting membrane peeling—and extraocular surgeries—posterior scleral reinforcement (PSR)⁵ and combined surgery⁶. However, there is increasing evidence⁷ that the outcomes of a single intraocular surgery are often unsatisfactory. Conart et al. reported that 8.5% of 47 highly myopic eyes with macular detachment treated with PPV had recurrence after surgery⁸. Besides, PPV is a complicated and potentially damaging intraocular surgery that is associated with a risk of complications after combined silicone oil filling, such as glaucoma, cataracts, and risks associated with silicone oil removal.

Although MFS is primarily associated with posterior scleral staphyloma, its pathogenesis remains unknown⁹. MFS develops due to the pulling action of posterior scleral staphyloma because the retina lacks the ductility to match the expansion of the sclera¹⁰. PPV relieves the tangential and centrifugal traction forces caused by the vitreous cortex without tackling the persistently expanding posterior scleral staphyloma^{11–12}, which is the fundamental reason for its poor clinical outcome. In contrast, PSR¹³ can shorten a patient's axial length (AL) and reinforce the posterior scleral staphyloma, while reducing the retinal traction caused by the vitreous and posterior scleral staphyloma. Furthermore, several studies^{7, 14–15} have indicated that the efficacy of PSR for the treatment of MFS is superior to that of PPV. However, differences in the material and shape of the scleral strip used can affect the outcome of the surgery.

Several studies have focused on the clinical outcomes of posterior scleral reinforcement surgery, most of which evaluate the postoperative retinal structural reattachment. The purpose of this study was to investigate the effectiveness and safety of PSR for the treatment of MFS by evaluating both the structure and function of the retina.

Methods

This was a prospective study of 32 eyes from 20 patients with MFS who were treated using PSR at the Tianjin Medical University Eye Hospital from January 2018 to April 2019. Ethical approval for this study was obtained from the Medical Ethics Committee of Tianjin Medical University Eye Hospital. The study procedures adhered to the tenets of the Declaration of Helsinki. All patients included in this study provided written informed consent after thorough discussions on the potential benefits and risks of PSR combined with vitrectomy.

Patients with choroidal neovascularisation, retinal detachment, and a history of ocular surgery were excluded from this study. All patients with MFS were assessed postoperatively during follow-up visits at 1, 3, 6 months, and 1 year or longer. The preoperative and postoperative examinations included slit lamp examination, measurement of best corrected visual acuity (BCVA) (Logarithm of the Minimum Angle of Resolution, logMAR), refraction, measurement of intraocular pressure (IOP), measurement of axial length (AL), optical coherence tomography (OCT), and electroretinogram (ERG). AL was measured using Lenstar LS900 (Haag-StreitAG, Switzerland), and the average of three successive measurements was calculated and recorded. OCT (OPTOVUE, Colin, USA) was used for fundus examination; the radial scan was performed with the central macular recess as the centre, and the diameter of the scan was 6 mm. The average of the maximum length of the macular schisis cavity in 12 directions within the scan range was measured, and the reduction of the macular schisis cavity was calculated from this average. The evaluation criteria for macular restoration were as follows⁵: an 80% or more reduction of the macular schisis cavity was considered essential reattachment, a 40%–79% reduction was considered partial reattachment, and a reduction of less than 39% was considered as not reattached. ERG results were examined using a retinal current meter (ESPION, Diagnosys, USA), and a-wave and b-wave amplitudes were recorded.

Surgery procedure

All the surgeries were performed by the same experienced doctor under a microscope. All the patients signed a consent form before the surgery. The strips used for the surgery were homogeneous sclerae that were cross-linked and rigorously sterilised using 0.1% genipin¹⁶. Each strip was shuttle-shaped, 1.5 times as long as the AL of the patient's eye, and 0.4 times as wide as the AL of the eye. The intraoperative shortening of the AL was expected to range from approximately 2–3 mm. The details of the surgical technique of the PSR have been published previously¹⁷. After general anesthesia was induced, the bulbar conjunctiva was cut at 210° along the corneal limbus, with the inferior temporal aspect of the eye as the centre. The lateral rectus and inferior rectus traction lines were made, the strips were drawn inwards and upwards and passed through the inferior oblique, lateral rectus, and inferior rectus muscles in turn. 5-0 non-absorbable sutures (Alcon) were fixed to the equatorial anterior sclera between the inferior and medial recti muscles, and the lateral temporal end was fixed to the equatorial sclera between the superior and lateral recti muscles. Before fixation, the anterior chamber was punctured using a 5-gauge needle to release two to four drops of atrial fluid to balance the intraocular pressure. Before the procedure was completed, the strip was checked to ensure that it was in the correct position and orientation. The posterior pole was examined using indirect ophthalmoscopy after pupil dilation to confirm that the optic nerve and major vessels were normal and the macula was mildly elevated. The conjunctival incision was closed using 8-0 absorbable sutures coated with antibiotic eye ointment and bandaged.

Statistical analysis

Statistical analysis was performed using SPSS software (version 23.0; StataCorp LP, College Station, TX, USA). Data for continuous variables were expressed as mean $\pm$ standard deviation. Preoperative and postoperative LogMAR BCVA, ERG, AL, and IOP were compared using analysis of variance for repeated measurements. $p < 0.05$ indicated a statistically significant difference.

Results

The patients' demographic data are presented in Table 1. The participants included three men and 17 women, with a mean age of 51.20 ± 14.82 years. The mean duration of follow-up was 17.80 ± 8.74 months.

Table 1

Preoperative data of the patients who underwent posterior scleral reinforcement for myopic foveoschisis versus their postoperative data recorded at the last follow up

No.	Sex	Age	Eye	Preoperative				Post-operative								Folk up (mo)	
				SE (D)	BCVA	AL (mm)	OCT	ERG a(μV)	ERG b(μV)	SE (D)	BCVA	AL (mm)	OCT (MFS)	OCT (MH)	ERG a(μV)		ERG b(μV)
1	F	31	OD	-7.5	0.1	31.98	MFS	32.79	75.28	-6	0.1	31.03	ER	-	42.81	146.7	36
			OS	-13	0.4	33.51	MFS	20.61	61.68	-5.5	0.4	31.55	ER	-	48.43	124.9	36
2	F	18	OD	-14.5	0.1	28.26	MFS	34.68	60.2	-11.5	0.1	27.05	ER	-	36.8	99.34	12
			OS	-11.5	0.4	27.25	MFS	29.13	64.06	-10	0	26.47	ER	-	45.61	111.6	12
3	F	34	OD	-4.5	0.2	31.4	MFS	39.85	60.29	-4	0.1	31.31	ER	-	65.2	123.1	13
4	F	40	OD	-16	1.3	30.83	MFS	24.14	66.61	-2	1	30.06	PR	-	36.42	96.65	12
5	F	59	OS	-14	0.5	28.49	MFSMH	34.09	94.53	-12	0.5	26.61	ER	closure	43.57	105.1	42
6	M	33	OS	-7.75	0.2	32.79	MFS MH	24.12	114.9	-6.5	0.3	31.96	ER	closure	38.07	57.23	12
7	F	53	OD	-2.25	0.9	30.68	MFS MH	32.82	49.08	-0.75	0.4	28.88	ER	MH	39.24	101.7	12
			OS	-2.5	0.4	29.29	MFS MH	49.7	56.15	-0.25	0	27.73	ER	closure	42.91	99.42	12
8	F	69	OD	-24.5	1.6	30.93	MFS MH	22.57	38.77	-2.5	0.7	27.44	ER	closure	26.92	45.52	14
9	F	77	OD	-4	1.3	32.17	MFS	30.75	47.34	-1	1	29.66	ER	-	49.04	51.42	12
			OS	-3.5	1	30.89	MFS MH	90.96	128.9	-0.25	0.3	28.48	ER	MH	110.5	157.1	12
10	F	53	OD	-13.75	1.6	27.17	MF	58.07	107.9	-6.25	1.6	25.4	ER	-	51.41	106.9	12
			OS	-17	0.5	29.18	MF	28.6	109.1	-12	0.3	27.35	ER	-	45.56	124	12
11	F	60	OD	-24	1.6	30.79	MFS MH	21.17	34.55	-22.5	1.6	27.54	ER	closure	29.99	66.55	29
			OS	-22.5	0.7	28.79	MFS	25.66	69.78	-17	0.5	26.89	ER	-	35.24	138.2	29
12	F	61	OD	-12	0.3	28.72	MFS	33.5	93.04	-3.5	0.2	27.14	ER	-	21.45	41.15	24
13	F	58	OD	-13.75	0.5	26.49	MFS	28.44	47.63	-5.25	0.3	25.45	ER	-	43.24	140	12
14	F	59	OD	-21.5	0.5	29.59	MFS	44.97	99.31	-12	0.4	26.62	ER	-	57.35	121.35	12
			OS	-22.25	1.3	31.02	MFS MH	33.46	80.78	-14	1.3	28.35	ER	closure	9.12	102.44	12
15	F	64	OD	-24.75	1.6	32.03	MFS MH	27.63	61.51	-20	1.6	30.31	ER	closure	26.34	97.68	12
			OS	-26.5	1	31.79	MFS	19.38	40.01	-17	0.8	29.01	ER	-	47.26	89.56	12
16	F	49	OD	-11.75	0.7	30.13	MFS	32.24	105	-17	0.8	29.41	ER	-	47.69	98.77	12
			OS	-3.75	0.7	29.85	MFS	35.96	104.4	-1.5	0.4	28.13	ER	-	46.37	103.24	12
17	M	49	OD	-26.5	0.8	32.18	MFS	39.32	130.8	-3.25	0.2	30.63	ER	-	26.79	85.85	14
			OS	-26.5	0.8	31.33	MFS	34.12	117.3	-2.5	0.7	29.48	ER	-	22.65	66.94	14
18	M	31	OD	-21	0.2	31.62	MFS	38.98	60.53	-20	0.2	31.57	ER	-	45.67	89.79	25
19	F	62	OD	-21	1.6	30.3	MFS	15.51	47.82	-18.5	1.5	28.46	ER	-	21.47	44.6	20
			OS	-14.5	0.4	27.52	MFS	13.38	52.64	-11	0.3	26.92	ER	-	34.24	55.82	20
20	F	59	OD	-23	1	27.87	MFS	39.42	112.1	-21	0.7	26.91	PR	-	28.22	61.85	19
			OS	-24.5	1.3	27.02	MFS	31.42	94.67	-11	1.3	25.61	ER	-	24.77	55.22	19
Abbreviations: SE, spherical equivalent; BCVA, best corrected vision acuity; AL, axial length; MFS, myopic foveoschisis; MH, macular hole; ER, essentially reattached; PR, partially reattached; ERG, electroretinogram; OD, right eye; OS, left eye; OCT, optical coherence tomography																	

The postoperative changes in the spherical equivalent of refractive error (SE), BCVA, AL, and ERG at the end of follow-up are shown in Table 2. Compared with the preoperative data, the postoperative changes in these variables were statistically significant. The changes in AL outlined in Figure 1 indicate that although AL was shortened after the surgery, there was an increase in AL during the 6 months after the surgery. However, the mean AL was stable after 6 months, and the final AL reduction recorded was 1.64 ± 0.85 mm.

Table 2
The results of preoperative and postoperative examinations

	Preoperative	Postoperative	<i>P</i>
SE (D)	-15.50±8.02	-9.29±7.01	<0.05
BCVA (logMAR)	0.80±0.49	0.62±0.50	<0.05
AL (mm)	30.06±1.87	28.42±1.91	<0.05
IOP (mmHg)	13.37±2.42	13.72±2.08	>0.05
ERG a(μV)	33.36±14.10	40.32±17.51	<0.05
ERG b(μV)	77.71±28.64	94.05±31.89	<0.05
Abbreviations: SE, spherical equivalent; BCVA, best corrected vision acuity; AL, axial length; IOP, intraocular pressure; ERG, electrocardiogram			

Preoperative OCT scans revealed that all eyes had MFS, whereas nine eyes had macular holes (MH) as well. Data recorded at the last follow-up showed that the fovea was essentially reattached in 30 eyes (93.75%), and partially reattached in two eyes (6.25%). The macular holes in seven eyes (77.78%) were closed at the last follow-up. Figure 2 presents the preoperative and postoperative changes in the OCT scans of patients 5, 8 and 10.

Five eyes (15.63%) had transiently high IOP after surgery, which was controlled using IOP-lowering drops. All patients had visual distortion but no serious complications such as retinal detachment and vitreous haemorrhage.

Discussion

In this study, we assessed the efficacy and safety of PSR for the treatment of MFS. Our results showed a slight increase in AL in the first 6 months after surgery; however, the mean AL stabilised after 6 months. This finding is similar to those reported by Zhu et al¹⁷. MFS is the main cause of vision loss in patients with pathological myopia. Although the pathogenesis of MFS is unknown, it is presently considered to be related to two factors, which are as follows^{9, 18, 19}: The tangential traction between the posterior vitreous cortex and the inner limiting membrane, and the mismatch between the retina and the externally expanded scleral tissue. The latter is considered to be the main cause of MFS. AL stability is important for the treatment of MFS, as well as for the prevention of recurrence.

Data recorded at the last follow-up in the present study showed that the fovea was essentially reattached in 30 eyes (93.75%) and partially reattached in two eyes (6.25%). Several studies^{20–22} have shown reattachment rates of 83.3–100% for MFS treated using PSR, with variances occurring due to differences in the shape and material of the strips used intraoperatively and due to variations in the duration of the study observations. Micol et al.⁷ found that resolution of foveoschisis, retinal reattachment, and MH closure seem to be achieved more frequently with macular buckle than with PPV. The duration of retinal reattachment may be related to the position of the intraoperative strip, the duration and diameter of the foveal retinoschisis, and the shape of the posterior scleral staphyloma. The strip material used in this study was chosen from donor sclerae and sterilised and cross-linked with genipin for increased strength and resistance to degradation, which is beneficial for the prevention of posterior scleral expansion and maintenance of long-term surgical outcomes²³. The length and width of the strip should be pre-designed before PSR to ensure that it can completely wrap around the macula and posterior scleral staphyloma^{5, 10}. The vortex vein, optic nerve, and other important tissues should be avoided while positioning the strip to avoid disrupting the blood supply to the eye and affecting vision. The mean duration of follow-up in the study was 17.80 ± 8.74 months, which indicates that the surgical outcomes were stable 1 year after surgery. However, further follow-up is needed to determine the long-term outcomes of the surgery. The MH in seven eyes (77.78%) in the present study closed after surgery. Ikuno et al.²⁴ reported that the rate of MH closure in patients with high myopia who underwent PPV surgery in their study was 25%. The two patients in the present study who had no MH closure showed improved visual acuity and retinal reattachment. Thus, we believe that we can continue to observe fundus changes and that no further surgical intervention is needed.

Several authors^{25–26} concluded that high myopia causes a decrease in ERG a-wave and b-wave amplitudes in patients and that photopic readings reflect the cellular electrical activities of the retinal layers, from the photoreceptor cells in the macular region to the amacrine cells. Westall et al.²⁷ concluded that altered retinal cone cell responses appear earlier and are more impaired than those of optic rods in patients with MFS. Therefore, we used photopic ERG to determine whether surgery could offer an improvement in retinal function. Our results showed that the postoperative a-wave and b-wave amplitudes of the patients were significantly improved compared with the preoperative data and that the difference was statistically significant ($p < 0.05$). This indicates that retinal function could be improved using PSR. The preoperative BCVA of the patients in the present study was 0.80 ± 0.49 , whereas the postoperative BCVA was 0.62 ± 0.50 ($p = 0.05$). This increase in BCVA may be attributed to the effect of mechanical pressure on the sclera in the posterior pole by the PSR, which can reattach the fovea and delay the increase in AL. In addition, due to the stimulating effect of the allograft sclera, neovascularisation develops in the sclera and the blood supply to the corresponding parts of the retina and choroid is improved, thereby promoting metabolism in the optic cells.

All transient elevations in IOP during the early postoperative period subsided with the use of IOP-lowering drops. The difference between the IOP recorded at the last postoperative follow-up and that recorded during the preoperative period was not statistically significant ($p=0.05$), suggesting that the shortening of the AL during surgery did not affect the circulation of aqueous humour. The postoperative visual distortion is related to the macular fold caused by the PSR, which is a direct confirmation of the effectiveness of the surgery. As the foveal retinoschisis gradually repairs and the folds gradually flatten, the visual distortion progressively improves and eventually disappears. No serious postoperative complications, such as retinal detachment and vitreous haemorrhage, occurred in the present study, indicating the safety of the surgery.

This study has some limitations. First, the observation period was short and the sample size is small. Second, no control group was established and few indicators of fundus function were evaluated. Considering the complicated pathogenesis of MFS, a large number of long-term clinical studies are needed to verify the long-term efficacy of PSR. In addition, the difference between the efficacy of PSR treatment alone and PSR combined with PPV for MFS needs to be evaluated.

Conclusion

In conclusion, PSR can achieve anatomical reattachment of the fovea and resolution of retinoschisis by shortening the AL. It can improve retinal function with few postoperative complications, making it a safe and effective method for the treatment of MFS.

List Of Abbreviations

AL Axial length

BCVA Best corrected visual acuity

MFS Myopic foveoschisis

MH Macular holes

OCT Optical coherence tomography

PPV Pars plana vitrectomy

PSR Posterior scleral reinforcement

Declarations

Ethics approval and consent to participate

Ethical approval for this study was obtained from the Medical Ethics Committee of Tianjin Medical University Eye Hospital. The study procedures adhered to the tenets of the Declaration of Helsinki

Consent for publication We obtained written informed consent for publication from the patients related to details and images.

Availability of data and materials The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Competing interests The authors declare that they have no competing interests

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Authors' contributions

All authors contributed to the study's conception and design. Material preparation, data collection and analysis were performed by Qing He, Xiu Wang and Caiyuan Xie. The first draft of the manuscript was written by Qing He and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript. The authors would like to thank Editage (www.editage.cn) for English language editing.

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Figures

Figure 1

Changes in axial length after posterior scleral reinforcement surgery in 32 eyes

Image not available with this version

Figure 2

Figure 2 presents the preoperative and postoperative changes in the OCT scans of patients 5, 8 and 10.