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RETINAL DISORDERS

Observation of macular hole associated with retinoschisis in patients with high myopia

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Abstract

Purpose To observe the characteristics of highly myopic macular holes (HMMHs) with macular retinoschisis (MRS) by optical coherence tomography (OCT) and explore the possible relationship between HMMHs and different types of MRS.

Methods We consecutively reviewed the clinical data and OCT images of the patients with HMMHs from June 2015 to February 2021. Then we picked eyes with MRS from these HMMHs for analysis. The minimum linear diameter (MLD), basal diameter (BD), and height (H) of HMMHs were measured. HMMHs were grouped according to the extent or layer involvement of the concomitant MRS and the characteristics were compared among groups. The impact of MRS on the MLD of macular hole was analyzed with multivariable linear regression.

Results We included 127 patients with MRS from 168 HMMHs (75.5%) for analysis.

According to the different classification systems, the most frequent type of MRS in HMMHs was S3 (foveal but not entire macular area MRS) (62.2%) and both inner- and outer- (I/O-MRS) involved types. In our study, HMMHs with more extensive MRS had larger MLD, larger BD, larger H, and poorer best-corrected visual acuity (BCVA). Meanwhile, HMMHs with outer layer-involved MRS (outer MRS and I/O-MRS) had larger BD than HMMH with only inner layer-involved MRS. (All $P < 0.05$) Multivariable linear regression further illustrated only the extent of MRS was significantly associated with the MLD of HMMH, while there was no significant correlation between the involved retinal layers and the MLD of HMMH.

Conclusion HMMH with MRS presented as a predominant type in HMMHs. The MRS was always with a relatively large extent and involved both inner and outer layers. MLD of HMMH was mainly affected by the extent of MRS.

Keywords High myopia · Macular hole · Macular retinoschisis · Optical coherence tomography

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Key messages

- Previous studies have confirmed that highly myopic macular hole (HMMH) was often associated with macular retinoschisis (MRS) and the MRS itself is a complex lesion that can be divided into different types according to the extent and layer involvement. However, we have little information on the distribution and extent of MRS in HMMHs.
- By observing the MRS in HMMH, we found that 75.5% of HMMHs presented with MRS, and the MRS was always with a relatively large extent and involved both inner and outer layers.
- We also found HMMHs with more extensive MRS had larger diameter of the hole and poorer best-corrected visual acuity, and HMMHs with outer layer involved MRS had larger basal diameter than HMMH with only inner layer involved MRS.
- Minimum linear diameter (MLD) of HMMH was mainly affected by the extent of MRS, while there was no significant correlation between the involved retinal layers and the MLD of HMMH.

Introduction

High myopia, which is always defined as a refractive error less than – 6 diopters or an axial length (AXL) greater than 26.0 mm, has a high incidence rate in Asia (6.8–21.6%) [1, 2]. It can result in fundus lesions, and one of its common complications is the macular hole (MH), which can cause severe vision loss and reduced life quality [3].

Owing to the existence of a posterior staphyloma, highly myopic macular holes (HMMH) is often associated with macular retinoschisis (MRS), which is one of its major differences from an emmetropic MH [4–6]. Previous studies have shown that HMMH with MRS was generally associated with a worse surgical prognosis [7, 8]. In high myopia, both MRS and MH belong to myopic traction maculopathy [9]. It is generally accepted that HMMHs can develop from MRS [5, 10–12]. Therefore, before removing the traction on retina with pars plana vitrectomy and internal limiting membrane peeling, MRS may have a particular impact on HMMH [7, 8].

In addition, MRS itself is a complex lesion that can be divided into different types according to the extent and layer involvement [6, 13]. Various studies have argued that the rate of progression and the degree of vision loss vary among different types of MRS [3, 6, 14]. However, few studies paid attention on the differences in MRS that accompany with HMMH, and there is no complete understanding of diverse MRS in the occurrence and development of HMMH. In light of all these considerations, by observing the characteristics of HMMHs with MRS in a large sample, this study tried to explore the relationship between different types of MRS and HMMH. We may have a deeper understanding of the formation of HMMH and provide more guidance for the clinical diagnosis.

Methods

Participants and materials

We collected highly myopic macular holes based on clinical data, fundus examination, and optical coherence tomography (OCT) images in Beijing Tongren Hospital from June 2015 to February 2021 and selected HMMHs with MRS for retrospective analysis. High myopia was defined as an AXL > 26.00 mm. Exclusion criteria were as follows: severe cataract, history of other ocular surgery, traumatic macular holes, amblyopia, severe glaucoma, uveitis, optic neuritis, and severe systemic disease affecting ocular health. This study protocol adhered to the Helsinki Declaration and its lateral amendments, and was approved by the ethical review committee of Beijing Tongren Hospital, Capital Medical University. All included participants signed informed consents.

Comprehensive ophthalmic examination

All subjects underwent comprehensive ophthalmic examinations. Best-corrected visual acuity (BCVA) was measured by standard Snellen acuity charts. Intraocular pressure (IOP) was measured by noncontact tonometry (Full Auto Tonometer TX-F; Canon Canada, Quebec). AXL of the eyeball was measured using IOL Master Biometry (Carl Zeiss Meditec, Jena, Germany). Color fundus photography was performed by fundus camera (TRC-50; Topcon, Tokyo, Japan). OCT image was achieved by high-definition OCT (Cirrus high-definition OCT; Carl Zeiss, Dublin, CA).

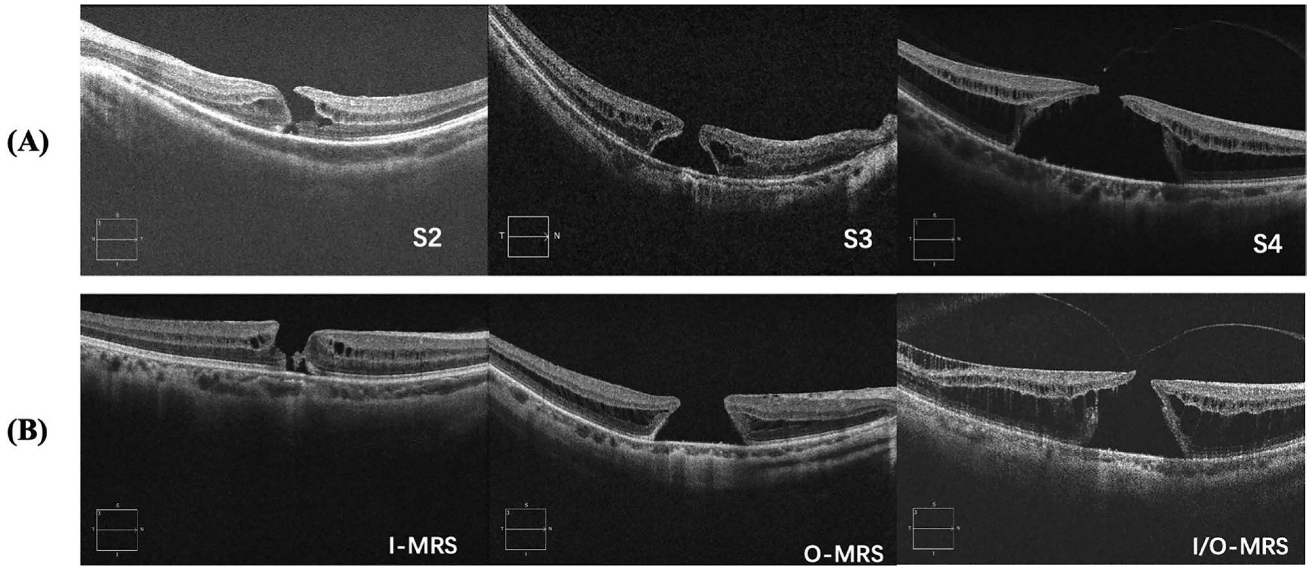

Fig. 1 The optical coherence tomography (OCT) images of highly myopic macular holes (HMMHs) with macular retinoschisis (MRS) in diverse types according to two different classification methods. **A** Three types of HMMHs with MRS according to the extent of MRS classification. S2, fovea-only macular retinoschisis; S3, foveal but not entire macular area macular retinoschisis; S4, entire macular area macular retinoschisis. **B** Three types of HMMHs with MRS according to the MRS layer involvement classification. I-MRS, only inner retinoschisis; O-MRS, only outer retinoschisis; I/O-MRS, both inner and outer retinoschisis

OCT image evaluations

Optical coherence tomography examinations using 6-mm Line B-scans were performed horizontally and vertically through the center of the macular hole. The OCT scans were repeated at least once to ensure the quality of every image.

Measurement of parameters about macular hole: in the horizontal direction, minimum linear diameter (MLD), basal diameter (BD), and height (H) were measured by the caliper function of OCT using methods described in the previous studies [15]. The foveal area was defined as a region with a diameter of 1500 µm (consistent with the average optic disc diameter) centered on the macular hole [16]. The macular area was defined as an area with a diameter of 6 mm centered on the fovea [16]. Foveal retinal detachment was defined as the separation of the retinal neuroepithelial layer and retinal pigment epithelial layer confined to the macular area [17]. Vitreous macular traction (VMT), epiretinal membrane, and internal limiting membrane (ILM) detachment were also recorded.

Classification of HMMH with MRS

According to the classification by Shimada et al. [6] for the extent of outer MRS, these HMMHs were further classified (Fig. 1A): extra-foveal macular retinoschisis (S1); fovea-only macular retinoschisis (S2), foveal but not entire macular area macular retinoschisis (S3), and entire macular area macular retinoschisis (S4). The HMMH were classified according to the extent of inner MRS if the schisis involved only inner layer.

In addition, these HMMHs were divided into three subgroups according to the classification by Ceklic [13] based on the layer involvement of MRS (Fig. 1B): only inner retinoschisis (I-MRS), only outer retinoschisis (O-MRS), and both inner and outer retinoschisis (I/O-MRS). Inner retinoschisis can occur in inner nuclear layer, inner plexiform layer, ganglion cell layer, and retinal fiber layer. Outer retinoschisis can occur in outer plexiform layer and outer nuclear layer.

Statistics

BCVA were converted to the logarithm of the minimum angle of resolution (logMAR) scale in the statistical analyses. We checked all continuous variables for normal distribution first. When the variable corresponded to normal distribution, the presentation as mean ± standard deviation and the one-way analysis of variance was used, while non-normally distributed variables were presented as a median with an interquartile range, and used Kruskal–Wallis *H* test and Mann–Whitney *U* test. Pearson's chi-square test and Fisher's exact test were used for categorical variables. When assessing regarding the gender, we excluded the eye with smaller MLD

Table 1 Characteristics of patients with macular retinoschisis

Characteristics	
Gender	
Male (*n*, %)	43 (34.1)
Female (*n*, %)	83 (65.9)
Eye	
Right (*n*, %)	71 (55.9)
Left (*n*, %)	56 (44.1)
Age, years	54.79 ± 9.58 (28–77)
Duration of symptoms, months	7.75 ± 13.07 (0.50–120)
Log MAR BCVA	0.96 ± 0.41 (0.10–2.00)
IOP, mmHg	15.39 ± 3.39 (4–29)
AXL, mm	28.38 ± 1.99 (26.05–34.44)
MLD, μm	478.17 ± 187.93 (96–1062)
BD, μm	1183.48 ± 700.46 (270–4683)
H, μm	493.26 ± 153.88 (248.50–1152.50)
fRD/eyes (*n*, %)	16 (12.5)
VMT/eyes (*n*, %)	21 (16.5)
ERM/eyes (*n*, %)	62 (48.8)
ILM detachment/eyes (*n*, %)	9 (7.0)

BCVA, best-corrected visual acuity; *IOP*, intraocular pressure; *AXL*, axial length; *MLD*, minimum linear diameter; *BD*, basal diameter; *H*, macular hole height; *fRD*, foveal retinal detachment; *VMT*, vitreomacular traction; *ERM*, epiretinal membrane; *ILM*, inner limiting membrane

of bilateral patient. Because MLD was always used as a good standard of management of MH, univariate and multivariable linear regression modelling was used to assess the impact of MRS on the MLD of HMMHs [18]. The variables included in multivariable regression was with a *P* value less than 0.1 in univariate regression. $P < 0.05$ was considered statistically significant. SPSS Statistics v26.0 (IBM, Chicago, IL) was used for all statistical analyses.

Results

Clinical characteristics

We enrolled 127 eyes with MRS of 126 people selected from 168 HMMH eyes, and the proportion of HMMH with MRS was 75.5%. Table 1 shows the baseline characteristics of these eyes. The mean age was 54.79 ± 9.58 years and the mean logMAR BCVA was 0.96 ± 0.41. According to OCT findings, the mean MLD, B, and H of the HMMHs were 478.17 ± 187.93 μm, 1183.48 ± 700.46 μm, and 493.26 ± 153.88 μm, respectively. Sixteen eyes (12.5%) had a foveal retinal detachment.

Characteristics and comparisons of highly myopic macular holes in different types

Grouped by extent of MRS, no eye was classified as S1; 19 eyes (15.0%) were classified as S2; 79 eyes (62.2%) were classified as S3; 29 eyes (22.8%) were classified as S4 (Fig. 2A). The information and statistical results of these three groups are shown in Table 2. In this study, HMMHs with more extensive MRS had more women ($P = 0.031$), longer duration of symptoms ($P = 0.012$), and longer AXL ($P = 0.007$). The MLD, BD, and H of HMMHs were larger when the eyes combined with more extensive MRS ($P = 0.001$, $P < 0.001$, $P < 0.001$, respectively). In addition,

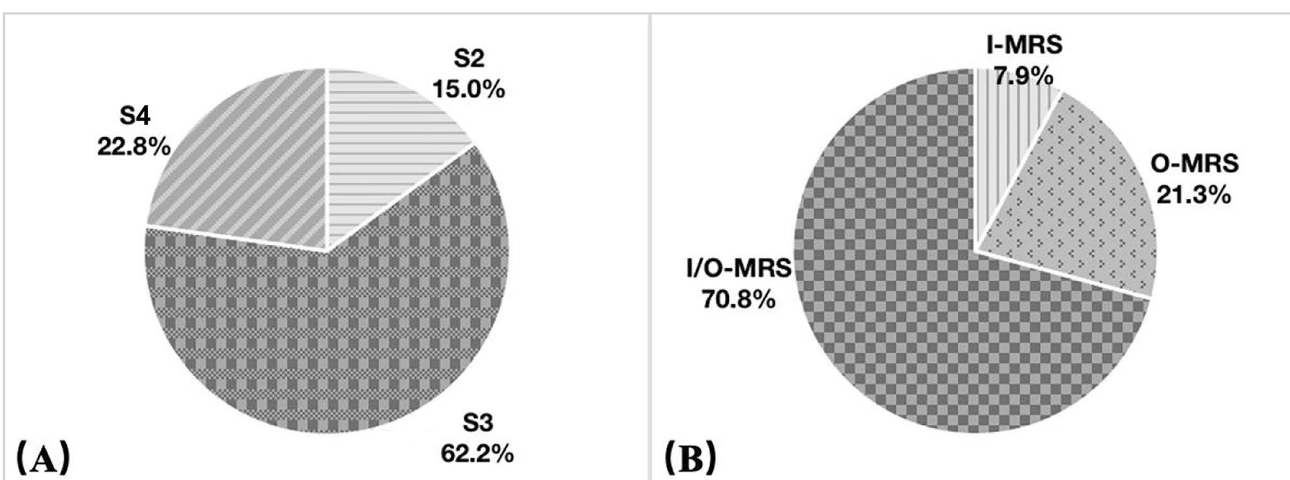

Fig. 2 **A** Distribution of three types of highly myopic macular holes (HMMHs) with macular retinoschisis (MRS) according to the MRS extent classification. S2, fovea-only macular retinoschisis; S3, foveal but not entire macular area macular retinoschisis; S4, entire macular area macular retinoschisis. **B** Distribution of three types of HMMHs with MRS according to the MRS layer involvement classification. I-MRS, only inner retinoschisis; O-MRS, only outer retinoschisis; I/O-MRS, both inner and outer retinoschisis

Table 2 The information and statistical results of the HMMHs in each group according to the extent of MRS

	S2 (*n* = 19)	S3 (*n* = 79)	S4 (*n* = 29)	Among 3 groups	S2 vs S3	S2 vs S4	S3 vs S4
Gender (M/F)	8/11	31/47	4/25	0.031[c]	1.000[c]	0.041[e]	0.019[c]
Age, years	57.89 ± 8.91 (44–74)	53.76 ± 8.79 (28–72)	55.61 ± 11.75 (32–77)	0.206[a]			
Duration of symptoms, months	3.00 (1.00, 5.00)	6.00 (3.00, 8.00)	6.00 (3.00, 10.00)	0.012[b]	0.008[d]	0.007[d]	0.393[d]
Log MAR BCVA (Snellen)	0.70 (0.30, 1.00)	1.00 (0.70, 1.30)	1.30 (0.73, 1.30)	0.011[b]	0.038[d]	0.007[d]	0.060[d]
IOP, mmHg	16.00 (14.00, 18.00)	15.00 (13.00, 17.00)	16.00 (13.00, 17.75)	0.217[b]			
AXL, mm	28.11 (26.51, 30.20)	27.47 (26.62, 28.81)	28.69 (27.66, 30.45)	0.007[b]	0.271[d]	0.337[d]	0.001[d]
MLD, µm	332.00 (199.00, 461.00)	512.00 (385.00, 629.00)	507.50 (298.50, 644.75)	0.001[b]	< 0.001[d]	0.013[d]	0.574[d]
BD, µm	674.00 (488.00, 839.00)	1023.00 (898.00, 1200.00)	1490.00 (1024.25, 2177.00)	< 0.001[b]	< 0.001[d]	< 0.001[d]	< 0.001[d]
H, µm	382.50 (355.00, 419.50)	444.00 (415.50, 487.50)	604.75 (540.63, 729.25)	< 0.001[b]	< 0.001[d]	< 0.001[d]	< 0.001[d]
fRD (*n*, %)	0 (0)	5 (6.3)	11 (37.9)	< 0.001[e]	0.580[e]	0.002[e]	< 0.001[c]
VMT (*n*, %)	3 (15.7)	11 (13.9)	7 (24.1)	0.482[e]			
ERM (*n*, %)	13 (68.4)	31 (39.2)	18 (62.0)	0.020[c]	0.038[c]	0.762[c]	0.049[c]
ILM detachment (*n*, %)	0 (0)	3 (3.7)	6 (20.6)	0.009[e]	1.000[e]	0.068[e]	0.011[e]

M, male; *F*, female; *BCVA*, best-corrected visual acuity; *IOP*, intraocular pressure; *AXL*, axial length; *MLD*, minimum linear diameter; *BD*, basal diameter; *H*, macular hole height; *fRD*, foveal retinal detachment; *VMT*, vitreomacular traction; *ERM*, epiretinal membrane; *ILM*, inner limiting membrane

Group S2, fovea-only macular retinoschisis; Group S3, foveal but not entire macular area macular retinoschisis; Group S4, entire macular area macular retinoschisis

[a]One-way ANOVA test

[b]Kruskal-Wallis *H* test

[c]Pearson chi-square test

[d]Mann-Whitney *U* test

[e]Fisher's exact test

this kind of HMMH may have more vitreoretinal traction factors, like ILM detachment ($P = 0.009$), and it were more likely to have foveal retinal detachment ($P < 0.001$). Furthermore, we found HMMHs with more extensive MRS had the poorer BCVA ($P = 0.011$).

Grouped by layer involvement of MRS, there were 10 eyes (7.9%) with I-MRS, 27 eyes (21.3%) with O-MRS, and 90 eyes (70.8%) with I/O-MRS (Fig. 2B). The statistical results of these three groups are shown in Table 3. Compared with I-MRS, the BD and H of groups involving outer layer (O-MRS and I/O-MRS) were larger ($P = 0.016$, $P = 0.014$, respectively), but there was no significant difference in MLD among these three groups ($P = 0.162$). In addition, ILM detachment and foveal retinal detachment were only observed in these two groups with outer layer involved. We also found the BCVA of group I/O-MRS or O-MRS was numerically poorer than group I-MRS, even though there was no statistical difference among these three groups.

Impact of macular retinoschisis on highly myopic macular hole

Age, gender, duration of symptom, AXL, the extent of MRS, the layer involvement of MRS, VMT, epiretinal membrane, and ILM detachment were included in regression to analyze the related factors of the MLD of macular hole. After univariate analysis, the factors with a *P* value less than 0.1 (AXL, the extent of MRS, VMT, epiretinal membrane) were included in the multivariate linear analysis and the results are shown in Table 4. We found the extent of MRS was the only factor associated with the MLD of HMMH. Taking HMMH with S2 MRS as reference, HMMH with S3 ($\beta = 0.472$; 95% CI, 91.998–272.327; $P < 0.001$) and HMMH with S4 ($\beta = 0.342$; 95% CI, 48.246–256.545; $P = 0.004$) were more likely to have larger MLD. However, the layer involvement of MRS was not significantly associated with the MLD of HMMH. No collinearity was found in the model.

Table 3 The information and statistical results of the HMMHs in each group according to the involved layer

	I-MRS (*n* = 10)	O-MRS (*n* = 27)	I/O-MRS (*n* = 90)	P			
				Among 3 groups	I-MRS vs O-MRS	I-MRS vs I/O-MRS	O-MRS vs I/O-MRS
Gender (M/F)	2/8	6/21	35/54	0.155[c]			
Age, years	54.50 ± 8.63	56.19 ± 11.05	54.40 ± 9.26	0.704[a]			
Duration of symptoms, months	4.00 (2.50, 5.25)	4.00 (2.00, 6.00)	6.00 (3.00, 12.00)	0.128[b]			
Log MAR BCVA (Snellen)	0.70 (0.49, 0.94)	1.00 (0.70, 1.30)	1.00 (0.70, 1.30)	0.196[b]			
IOP, mmHg	14.00 (11.75, 17.50)	15.00 (14.00, 17.00)	15.00 (13.00, 17.00)	0.688[b]			
AXL, mm	26.96 (26.68, 31.51)	28.17 (27.51, 30.48)	27.72 (26.59, 28.86)	0.157[b]			
MLD, µm	423.00 ± 190.81 (96–685)	430.63 ± 176.95 (104–697)	500.21 ± 189.442 (102–1062)	0.162[a]			
BD, µm	748.50 (548.75, 993.75)	896.00 (822.00, 1501.00)	1045.00 (919.50, 1305.50)	0.016[b]	0.044[d]	0.005[d]	0.382[d]
H, µm	402.50 (292.00, 453.00)	425.50 (397.50, 540.00)	466.50 (417.75, 544.50)	0.014[b]	0.098[d]	0.005[d]	0.205[d]
fRD (*n*, %)	0 (0)	4 (14.8)	12 (13.3)	0.675[e]			
VMT (*n*, %)	1 (10)	6 (22.2)	14 (15.5)	0.613[e]			
ERM (*n*, %)	3 (30)	13 (48.1)	46 (51.1)	0.468[c]			
ILM detachment (*n*, %)	0 (0)	2 (7.4)	7 (7.7)	1.000[e]			

BCVA, best-corrected visual acuity; *IOP*, intraocular pressure; *AXL*, axial length; *MLD*, minimum linear diameter; *BD*, basal diameter; *H*, macular hole height; *fRD*, foveal retinal detachment; *VMT*, vitreomacular traction; *ERM*, epiretinal membrane; *ILM*, inner limiting membrane

Group I-MRS, only inner retinoschisis; Group O-MRS, only outer retinoschisis; Group I/O-MRS, both inner and outer retinoschisis

[a]One-way ANOVA test

[b]Kruskal–Wallis *H* test

[c]Pearson chi-square test

[d]Mann-Whitney *U* test

[e]Fisher's exact test

Discussion

It is generally accepted that MRS and MH belong to myopic traction maculopathy, and HMMHs can develop from MRS [5, 9–12]. Therefore, there may be some relations between MRS and HMMH. In our study, 75.5% of HMMHs presented with MRS which was always with a relatively large extent and both inner and outer layers. By observing the clinical data of these enrolled eyes, we found some different characters of HMMHs with MRS in diverse types by two classification methods. Finally, we found there was an association between more extensive MRS and larger MLD of HMMH.

Our study did not find extra-foveal MRS (S1) concomitant with HMMHs; in other words, MRS was all connected with the edge of the hole. This may illustrate that the splitting fovea becomes so fragile that it is more likely to form a hole. Most studies agreed that retinal vessel stiffness could make inner retina less compliant and unable to adapt to the

Table 4 Univariate and multivariate regression analysis for minimum linear diameter of highly myopic macular holes

Variables	Univariate regression		Multivariate regression	
	β (95% CI)	*P* value	*β* (95% CI)	*P* value
AXL, mm	−0.207 (−35.866, −3.221)	0.019	−0.171*	0.050
The extent of MRS				
S2	Reference			
S3	0.472 (91.998, 272.327)	< 0.001	0.472 (91.998, 272.327)	< 0.001
S4	0.342 (48.246, 256.545)	0.004	0.342 (48.246, 256.545)	0.004
VMT	0.155 (−9.809, 166.416)	0.081	0.153*	0.072
ERM	0.151 (−9.052, 122.013)	0.091	0.090*	0.305

AXL, axial length; *CI*, confidence interval; *ERM*, epiretinal membrane; *MLD*, minimum linear diameter; *MRS*, macular retinoschisis; *VMT*, vitreomacular traction

Group S2, fovea-only macular retinoschisis; Group S3, foveal but not entire macular area macular retinoschisis; Group S4, entire macular area macular retinoschisis

*The variable was excluded by the stepwise method of multivariate regression analysis curvature of the outer retina and sclera, resulting in the splitting of retinal layers [19–21]. This type of retinoschisis often occurs at the extrafoveal retina because of the location of retinal vessels. In Shimada's study [6], only 6.3% S1 MRS showed progression in at least 2 years of follow-up, and all of them showed an increase in the area or height of MRS, with no progression to full-thickness MH. Therefore, from the point of macular hole, our study confirmed extrafoveal MRS is more stable and less likely to progress to MH over a short period, allowing for regular follow-up observation.

In our study, the morphological parameter of HMMH with more extensive MRS was larger. There may be the following explanations. Firstly, it is generally accepted that a more extensive area of MRS represents greater traction forces, resulting in the enlargement of the MH [4, 6]. Our findings confirmed that HMMHs with a larger extent of MRS had a longer AXL and a more significant proportion of ILM detachment. Second, the splitting retina itself, which was also a sign of traction forces, just as the ILM detachment, will affect the enlargement of MH. Finally, previous study elucidated MRS with large extent was more likely to have disruption of ellipsoid zone (EZ), and the intraretinal fluid could migrate from the retinoschisis gap through the EZ defect into the subretinal space. The accumulation of subretinal fluid may contribute to the progression of macular hole [4, 22]. While after comparing the characters between any two groups, we found there was no significant difference between groups S3 and S4 in MLD. This may be due to the large curvature of retina and sclera in high myopia. When a macular hole is high, it will have a smaller top diameter (Fig. 3).

With respect to the groups using the classification of the extent of MRS, there were some other findings. We found that HMMH with entire macular area MRS (S4) had longest AXL and most ILM detachment. The traction of a highly myopic eye has been presumed to result from multiple factors: the elongated AXL produces centrifugal force [23, 24]; vitreoretinal traction factors create centripetal traction [25]. In Fujimoto's study [26], ILM detachment was a sign of strong traction of the retina. All these phenomena may illustrate that S4 MRS was with a serious traction state. Shimada's study [6] and Cheng's [4] study had similar point. Strong traction may promote the lesion progress to a more serious state, and we found HMMH with S4 MRS was more likely to have foveal retinal detachment than the other groups. Combining all these points, we should be alert of the HMMH with S4 MRS and release the traction on retina as possible when handling it surgically. However, we found that no significant difference was noted regarding AXL between fovea-only MRS (S2) and the other two groups. And there were similar findings in Cheng's study [4], but they did not give a reasonable explanation. After reviewing the clinical data, we found the AXLs of five eyes (26.3%) in S2 group were greater than 30 mm. Previous studies have suggested that long AXL may not only produce centrifugal traction, it can also result in atrophy due to the reduction of choroidal circulation [27, 28]. Atrophic retina loses some tissue and becomes thinner, so it will have reduced elasticity and not be able to produce more deformation, that is, tractional maculopathy, like more extensive retinoschisis. Because of the presence of severe atrophy, this kind of HMMH may often have a suboptimal prognosis [5].

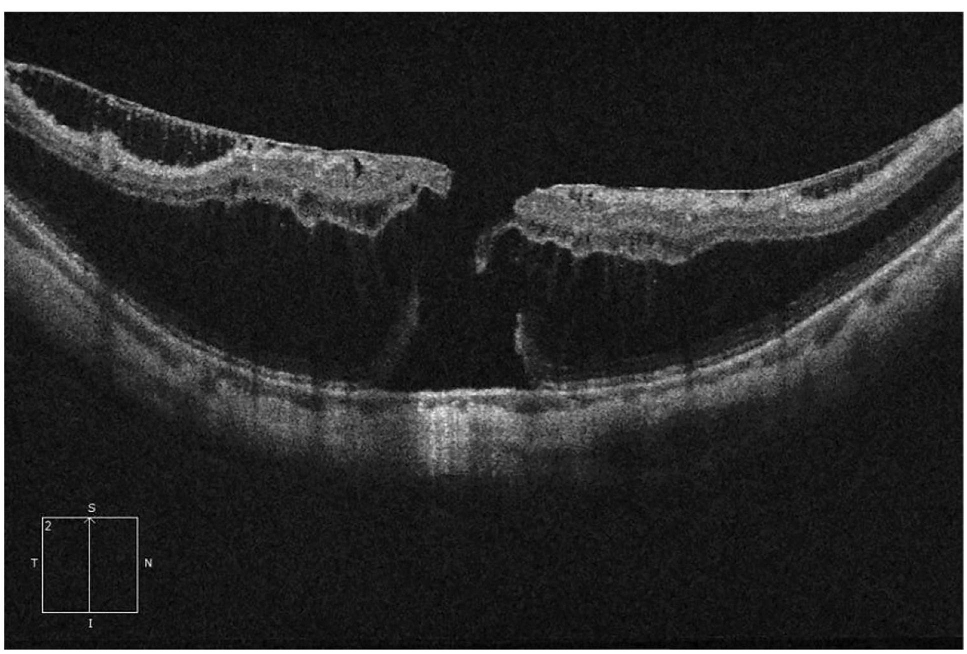

Fig. 3 An example of highly myopic macular hole (HMMH) with macular retinoschisis (MRS) that had a large height. This patient is a 57-year-old woman with an axial length of 29.35 mm. She had entire macular area retinoschisis (S4 MRS) and internal limiting membrane (ILM) detachment. Due to the large curvature of retina and sclera of this eye and the retinoschisis with a large height, the basal diameter of this macular hole is 1210 µm but the minimum linear diameter is only 309 µm

By observing the HMMHs in different types according to the layer involvement, we found HMMH with O-MRS or I/O-MRS had larger BD than HMMH with I-MRS. It could mean I-MRS should belong to a lower grade, and O-MRS and I/O-MRS should simultaneously belong to a higher grade. Li et al. [14] had a similar point. The pattern of MRS development may explain this: in highly myopic eyes, the macula is pulled by the vitreous body in the presence of posterior staphyloma curvature. At this moment, the inner layer is affected firstly, and then the outer layers of the retina are involved with the outward conduction of traction. We also found HMMHs with I-MRS had a smaller extent of MRS, indicating that the traction on HMMH is mild. In addition, Li et al. [14] found that I-MRS had a shorter AXL than the other two groups. In our study, AXL also had this trend, but there was no statistically significant difference due to the limited sample size of retrospective research. In the future, it may be necessary to design more prospective studies to explore this problem further.

Finally, we found the extent of MRS was the only risk factor of the MLD of HMMH, and it can also affect the visual function. MRS and macular hole both belong to a traction disease. The extent of MRS may represent the traction on the retina and the ability to produce deformation, and this viewpoint has been interpreted in the abovementioned discussion. The size of macular hole was associated with the disruption of photoreceptor and EZ band which were closely related with visual function [4]. Therefore, MLD may have a correlation with BCVA, and our study showed the visual acuity was progressively poorer from groups S2 to S4. However, we did not find a significant association between the layer involvement of MRS and MLD, possibly because the enlargement of the macular hole mainly depends on tangential traction, whereas the layer involvement of MRS primarily represents longitudinal traction [8]. Although the BCVA of the three groups did not show statistical difference, we can still find that the BCVA of I-MRS was better than the other two groups. This may illustrate that the outer layer can make a negative impact on BCVA.

Our study had some limitations: firstly, its retrospective nature led to a difference of sample size in each group; secondly, the samples in this study were recruited from a tertiary care hospital, which may lead to increased severe severity of the included cases; thirdly, posterior staphyloma was not compared because it could not be quantified on fundus image and OCT.

In conclusion, we summarized the characteristics of HMMH with different types of MRS by observing 127 eyes, and we found MRS in conjunction with the macular hole usually presented as S3 MRS and I/O-MRS. In our study, HMMH with more extensive MRS had larger MLD, BD, and H; and it was always accompanied by a poorer BCVA, more traction factors, and a more significant proportion of foveal retinal detachment. In addition, HMMH with MRS involving the outer layer was larger than I-MRS group. Finally, we revealed the extent of MRS was the only risk factor of MLD of HMMH. This study suggests that for patients with high myopia, the role of its concomitant retinoschisis on the development of macular hole cannot be ignored. For HMMH with extensive MRS and outer layer involved, timely intervention, like posterior scleral reinforcement or ILM peeling, should be carried out to reduce or release the traction on the retina, promote retinal reattachment, and prevent the progression of macular hole, so that the patients could get a better prognosis. This study may also be helpful for us to have a deeper understanding of the macular hole formation in high myopia and the relationship between MRS and HMMH. Further study regarding the surgical outcomes of HMMH along with different MRS was necessary in the future.

Declarations

Ethics approval All procedures performed in studies involving human participants were adhered to the Helsinki Declaration and its lateral amendments. Approval was granted by the ethical review committee of Beijing Tongren Hospital, Capital Medical University.

Consent to participate Informed consent was obtained from all individual participants included in this study.

Consent for publication Patients signed informed consent regarding publishing their data and photographs.

Conflict of interest The authors declare no competing interests.

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