·Clinical Research·

Application of optical coherence tomography angiography in assessment of posterior scleral reinforcement for pathologic myopia

Jing Mo[1], *An-Li Duan*[1], *Szy-Yann Chan*[1], *Xue-Fei Wang*[1], *Wen-Bin Wei*[1,2]

[1]Beijing Tongren Eye Center, Beijing Tongren Hospital, Capital Medical University, Beijing 100730, China
[2]Beijing Key Laboratory of Intraocular Tumor Diagnosis and Treatment, Beijing 100730, China
Correspondence to: Wen-Bin Wei. Beijing Tongren Eye Center, Beijing Tongren Hospital, Capital Medical University, Beijing 100730, China. weiwenbintr@163.com
Received: 2016-08-31 Accepted: 2016-11-16

Abstract

• AIM: To investigate the effect of posterior scleral reinforcement (PSR) on circulation of pathologic myopia eyes with posterior staphyloma by optical coherence tomography angiography (OCTA).

• METHODS: The study included 30 pathologic myopia eyes with posterior staphyloma which underwent PSR (PSR group) for 6 to 18mo ago, and 30 age and myopia matched eyes without PSR surgery as control group. Macular, choriocapillaris and radial peripapillary capillary (RPC) flow density were measured by OCTA, and the measurements were compared between groups.

• RESULTS: OCTA found no significant differences in macular flow density between PSR and control groups. For the superficial flow, whole enface flow density (WED), fovea density (FD), and parafoveal density (PD) were 46.55%±5.19% *vs* 47.29%±4.12% (P=0.542), 31.45%±6.35% *vs* 31.17%±4.48% (P=0.841), and 48.82%±5.66% *vs* 49.21%±4.15% (P=0.756) in PSR and control groups, respectively. For the deep flow, WED, FD, and PD were 52.07%±5.78% *vs* 53.95%±4.62% (P=0.168), 29.62%±6.55% *vs* 29.50%±6.38% (P=0.940), and 56.93%±6.17% *vs* 58.15%±5.13% (P=0.407) in PSR and control groups, respectively. The choriocapillary flow density was 61.18±3.25% in PSR group *vs* 60.88%±2.56% in control group (P=0.692). Also, OCTA found no significant differences in RPCs flow density between PSR and control groups. The optic disc WED, inside disc flow density and peripapillary flow density were 48.47%±4.77% *vs* 48.11%±4.57% (P=0.813), 45.47%±11.44% *vs* 46.68%±9.02% (P=0.709), 54.32%±5.29% *vs* 52.47%±6.62% (P=0.349) in PSR and control groups, respectively.

• CONCLUSION: OCTA provides a non-invasive and quantitative approach for monitoring macular and papillary blood flow in pathologic myopia. PSR can not improve but may maintain the circulation of pathologic myopia eyes with posterior staphyloma.

• **KEYWORDS:** optical coherence tomography angiography; posterior scleral reinforcement; pathologic myopia
DOI:10.18240/ijo.2016.12.10

Mo J, Duan AL, Chan SY, Wang XF, Wei WB. Application of optical coherence tomography angiography in assessment of posterior scleral reinforcement for pathologic myopia. *Int J Ophthalmol* 2016;9(12):1761-1765

INTRODUCTION

Pathologic myopia is one of the major causes of visual impairment and legal blindness worldwide[1-2], especially in East Asia [3-5]. The principal alterations in pathologic myopia include excessive axial elongation of the globe and associated deformation of the posterior ocular segment, with posterior staphyloma an important primary sign. Secondary to the increased axial length (AL) and staphyloma formation, a range of retinal and choroidal lesions may develop in the posterior pole in eyes with pathologic myopia[6-7].

It was reported that the presence of posterior staphyloma increased the frequency of severe pathologic changes such as chorioretinal atrophy, foveoschisis, and choroidal neovascularization (CNV)[8-10]. Thus, to prevent progression of posterior staphyloma might reduce the incidence of severe myopic maculopathy which could cause severe vision loss. Posterior scleral reinforcement (PSR), which was first proposed by Shevelev [11] and was later modified and simplified by Thompson [12], was being considered as treatment of eyes with pathologic myopia to prevent axial elongation and staphyloma progression by placing grafts over the posterior part of eyeballs. Some studies confirmed the efficacy and safety of PSR [13-15]. It was believed in PSR could slow the eye elongation by the direct mechanical force of the reinforcement band and/or by the sclera remodeling and hyperplasia, and to preserve the vision acuity by improvement of microcirculation within macula[16].

Optical coherence tomography angiography (OCTA) with split-spectrum amplitude-decorrelation angiography (SSADA) algorithmwas a recently developed clinical tool, which

allowed non-invasive and quantitative investigation of retinal and choroidal microvasculature [17-19]. By far there's few study to investigate the effect of PSR on microcirculation of pathologic myopia by OCTA.

The purpose of this study was to observe the changes in macular and peripapillary microcirculation of pathologic myopic eyes with posterior staphyloma after PSR by OCTA.

SUBJECTS AND METHODS

Subjects This observational, cross-sectional study enrolled 30 pathologic myopic eyes with posterior staphyloma (25 patients) treated with PSR (PSR group), and examined with OCTA between December 2015 to March 2016 in the Department of Ophthalmology of Beijing Tongren Hospital. At the same time 30 pathologic myopic eyes with posterior staphyloma (25 patients) untreated (control group), which were AL and mean spherical equivalent (MSE) matched with the status of PSR group before surgery, were recruited, also the age and gender of subjects were matched. The study protocol was approved by the Medical Ethics Committee of Beijing Tongren Hospital and written informed consents were obtained from all study participants.

Inclusion criteria included the following: MSE ≤-6.00 D, AL≥26.5 mm, and with posterior staphyloma.

Exclusion criteria included the following: 1) pathologic myopia with epiretinal membrane (ERM), foveoschisis, macular holes, CNV, and retinal detachment, because such maculopathy could interfere the analysis of flow density by OCTA; 2) having other ocular diseases such as glaucoma or any retinal vascular disease; 3) history of systemic diseases such as diabetes mellitus which might affect the ocular circulation; 4) history of intraocular surgery, laser photocoagulation, or ocular injury.

Methods

Surgical procedures All eyes in PSR group had been performed PSR by the same surgeon 6 to 18mo ago. The surgical techniques of PSR were basically following Thompson procedure, included placing a scleral buckle of donor sclera with a width of 6 to 10 mm onto the scleral surface of the macula, suturing the superior end of the buckle to the sclera at the nasal side of the scleral insertion of the superior rectus muscle, and suturing the inferior end of the buckle to the sclera at the nasal side of the scleral insertion of the inferior rectus muscle. The optic nerve placed the central part of the buckle to the macular region. After placing the scleral buckle, its location and the amount of the scleral indentation were checked by ophthalmoscopy. Care was taken to ensure that the buckle did not compress the optic nerve. By choosing a buckle width of 6 to 10 mm in dependence of the posterior segment stretching, the buckle covered the foveal region without compressing the optic nerve.

Outcome measures All study participants underwent a complete ophthalmic examination including: measurement of best corrected visual acuity (BCVA), refractive status using anautomatic refractometer (Auto Refractometer RM-8900 Topcon Inc, Tokyo, Japan), calculation of MSE using the spherical diopters plus one-half of the cylindrical diopters. Intraocular pressure (IOP) using non-contact tonometer (Full Auto Tonometer TX-F; Topcon, Tokyo, Japan). Slit-lamp assisted biomicroscopy (Haag-Streit, 3098 Koeniz, Switzerland), indirect ophthalmoscopy, and fundus photography (Hybrid Digital Mydriatic Retinal Camera CX-1 Canon Inc., Tokyo, Japan), AL using IOLMaster (CarlZeiss Inc., Jena, Germany). Blood pressure was also measured. And the pre-operation BCVA, IOP, AL, MSE of study eyes in PSR group were reviewed.

OCTA scans were obtained using the RTVue XR optical coherence tomography (Optovue Inc., Fremont, CA, USA. Software version 2015.100.0.35.) with the Angio Retina mode (3×3 mm) and the Angio Disc (4.5×4.5 mm) mode. The technique of OCTA including SSADA method had been described in detail recently [19-20]. Vascular flow density was defined as the percentage area occupied by vessels.

The exclusion criterions for OCTA scans were: 1) the signal strength index <40; 2) low quality of the images because of severe artefacts for poor fixation.

Retinal density of macular angiogram For measurement of retinal angiogram, a 3×3 mm macular angiogram of superficial and deep layers was analyzed using Optovue software with density function. On each layer (the superficial retinal layer and the deep retinal layer), flow density was separately calculated in 5 regions (fovea, tempo, superior, nasal, and inferior) based on ETDRS contour (Figure 1A). The whole enface flow density and parafovea flow density were also measured.

Choriocapillary density of macular angiogram For measurement of choriocapillary density, a 3×3 mm macular angiogram of choriocapillary layer was analyzed using Optovue software with flow function, which was able to calculate pixels of the blood flow. Choriocapillary density was calculated as vessel areas of choriocapillaris divided by selected areas (9 mm^2).

Radial peripapillary capillary flow density of disc angiogram For measurement of parameters of disc angiogram, a 4.5×4.5 mm large enface images was analyzed by applying Optovue software with density function. The software automatically defined the contour of optic disc as an inside elliptical annulus. Flow density of elliptical annulus area extending from contour of inside annulus to 0.75 mm outward was then separately calculated in 6 regions (nasal, inferior-nasal, inferior-tempo, superior-tempo, superior-nasal and tempo) based on the Garway-Heath Map (Figure 1B) on the RPC layer. The software also provided the whole enface

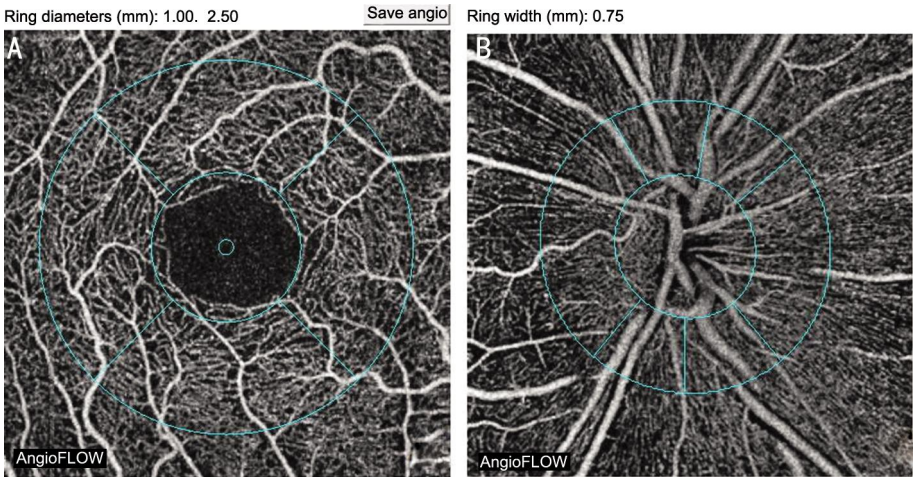

Figure 1 Angiograms of macula and optic disc A: Macular flow density was separately calculated in 5 regions (fovea, tempo, superior, nasal, and inferior) based on ETDRS contour. The whole enface flow density and parafovea flow density were also measured; B: RPCs flow density was separately calculated in 6 regions (nasal, inferior-nasal, inferior-tempo, superior-tempo, superior-nasal and tempo) based on the Garway-Heath Map. The whole enface, inside disc and peripapillary flow density were also measured.

flow density (WED), peripapillary flow density and inside disc flow density.

Statistical Analysis Statistical analysis was performed using a SPSS software package (SPSS for Mac, version 22, IBM/SPSS, Chicago, IL, USA). The mean and standard deviation of all the main parameters were analyzed. The t-test was used to compare the differences between groups. The χ^2 test was applied to analyze the frequency data of gender. A P value less than 0.05 were considered statistically significant.

RESULTS

Demographic and Clinical Data The demographic characteristics of PSR group before surgery and control group were presented in Table 1, there were no significant differences in gender, age, IOP, diastolic blood pressure (DBP), systolic blood pressure (SBP) between the two groups. Also, there were no differences in AL, MSE and BCVA between the control group and PSR group before surgery.

The mean AL before PSR was 30.04±1.96 mm, post PSR was 30.14±1.84 mm (P=0.093); the mean MSE before surgery was -15.73±4.13 D, post PSR was -15.78±3.99 D (P=0.761); the mean BCVA before PSR 0.49±0.30, post PSR was 0.52±0.30 (P=0.074). No significant differences were found before and post PSR.

Macular Flow Density OCTA found no significant differences in macular flow density between PSR and control groups. For the superficial and deep retinal flow, no significant differences were found in all those regions respectively (P>0.05). Also, no significant difference was found in choriocapillary flow density (P=0.692) (Table 2).

Radial Peripapillary Capillary Flow Density OCTA found no significant differences in radial peripapillary capillary (RPC) flow density between PSR and control groups. No significant differences were found in all those regions respectively (P>0.05) (Table 3).

Table 1 Demographic and ocular characteristics of two groups

Characteristics	PSR group (n=30)	Control group (n=30)	[a]P
Gender (M:F)	10:20	10:20	1.0000[b]
Age (a)	39.8±16.0	38.7±13.6	0.775
IOP (mm Hg)	15.8±2.1	15.2±2.6	0.279
SBP (mm Hg)	118±11	115±9	0.179
DBP (mm Hg)	76±7	77±6	0.486
MSE (D)	-15.73±4.13	-15.57±3.80	0.874
AL (mm)	30.04±1.96	29.75±1.57	0.542
BCVA	0.49±0.30	0.52±0.27	0.701

PSR: Posterior scleral reinforcement; BCVA: Best corrected visual acuity; IOP: Intraocular pressure; MSE: Mean spherical equivalence; AL: Axial length; SBP: Systolic blood pressure; DBP: Diastolic blood pressure. [a]Calculated by t-test; [b]Calculated by χ^2 test.

DISCUSSION

It is clear that pathologic myopia is a major public health problem worldwide and its disease burden likely to increase. While visual impairment in eyes with pathologic myopia is mainly due to the development of different types of myopic maculopathies. One study results indicated that myopic maculopathy tended to progress in approximately 40% of highly myopic eyes, and the development of a posterior staphyloma was critically important for the progression of myopic maculopathy. Preventive therapy targeting posterior staphyloma should be considered to prevent the visual impairment caused by progression of myopic maculopathy[20].

As a treatment option targeting posterior staphyloma, PSR had been mainly performed in Russia, China, and some groups in the United States and Australia. Studies revealed that PSR might delay or stop the axial elongation and halting the deterioration of vision in pathologic myopic eyes. It was thought that PSR could improve the microcirculation within macula by the secondary non-specific inflammatory reaction between the posterior sclera and the reinforcement band[16].

Table 2 Macular flow density of two groups %

Variables	PSR group (n=30)	Control group (n=30)	P
Superficial whole enface flow density	46.55±5.19	47.29±4.12	0.542
Superficial fovea flow density	31.45±6.35	31.17±4.48	0.841
Superficial parafovea flow density	48.82±5.66	49.21±4.15	0.756
Superficial temporal flow density	49.64±6.58	50.08±3.96	0.756
Superficial superior flow density	49.87±6.52	49.57±5.47	0.847
Superficial nasal flow density	48.02±6.60	48.39±4.71	0.805
Superficial inferior flow density	47.73±5.77	49.02±4.68	0.345
Deep whole enface flow density	52.07±5.78	53.95±4.62	0.168
Deep fovea flow density	29.62±6.55	29.50±6.38	0.940
Deep parafovea flow density	56.93±6.17	58.15±5.13	0.407
Deep temporal flow density	57.25±6.47	57.90±4.94	0.661
Deep superior flow density	56.64±7.69	57.61±6.09	0.588
Deep nasal flow density	57.48±6.12	58.15±5.31	0.649
Deep inferior flow density	56.33±6.80	58.92±6.91	0.150
Choriocapillary flow density	61.18±3.25	60.88±2.56	0.692

PSR: Posterior scleral reinforcement. P values were all calculated by t -test.

Table 3 RPCs flow density of two groups %

Variables	PSR group (n=30)	Control group (n=30)	P
Optic disc whole enface flow density	48.47±4.77	48.11±4.57	0.813
Optic disc inside disc flow density	45.47±11.44	46.68±9.02	0.709
Optic disc peripapillary flow density	54.32±5.29	52.47±6.62	0.349
Optic disc nasal flow density	50.59±5.08	48.56±8.21	0.374
Optic disc inferior nasal flow density	51.97±13.49	52.91±8.03	0.786
Optic disc inferior tempo flow density	58.71±9.06	57.82±8.48	0.751
Optic disc superior tempo flow density	55.71±9.35	54.60±10.25	0.726
Optic disc superior nasal flow density	49.27±13.67	48.70±9.82	0.879
Optic disc tempo flow density	59.82±6.03	55.80±11.52	0.199

PSR: Posterior scleral reinforcement. P values were all calculated by t -test.

But in the past years, though various techniques had been used to study ocular blood in pathologic myopia, such as fluorescein angiography (FA), indocyanine green angiography (ICGA), color Doppler imaging (CDI). But FA could not image the radial peripapillary or the deep capillary networks well, ICGA could not visualize the microvasculature well. In addition, FA and ICGA were not commonly used in myopia because of their invasive nature and difficulty in quantification. CDI was not sensitive enough to accurately measure the macular and peripapillary microcirculation. There's no satisfied tool to monitor microcirculation of retina and choroid, thus there's few study on the microcirculation changes post PSR in pathologic myopia eyes by far. Recent years OCTA was proven to document *in vivo* choroidal and retinal microvasculature in a noninvasive and quantitativeway, enabled high-resolution assessment of early and subtle changes in the macular and papillary vasculature. Good repeatability and reproducibility of OCTA techniques was reported in previous studies[18-19,21].

In this study, we observed 30 pathologic myopia eyes with posterior staphyloma which performed PSR 6 to 18mo ago by OCTA, measuring the macular, choriocapillaris and RPCs flow density; 30 age and myopia matched eyes without PSR surgery as control group. All measurements were compared between PSR group and control group, the results showed that in all regions there were no significant differences in macular, choriocapillaris and RPCs flow density between two groups. This indicated there were no obvious improvement or deterioration of circulation in macula and papilla after PSR. Maybe, with the separation of scleral, the secondary non-specific inflammatory reaction between the posterior sclera and the reinforcement band could hardly improve the blood flow of retina and choroid; but by slowing eye elongation, thinning and atrophy of retina and choroid might be halting, thus deterioration of circulation was prevented. In accordance with other studies [15,22], there're no significant changes in BCVA post PSR in this study. Our previous study revealed macular flow density was positively related to BCVA. The result of this study might explain why no significant improvement but a relative stabilization of BCVA was found after PSR.

This study had some limitations: it was a cross-sectional

study involving limited number of cases, controlled prospective study with larger sample size and longer follow-up was needed to further study the pathologic myopia ocular vasculature changes post PSR.

OCTA provided a non-invasive and quantitative approach for monitoring macular and papillary blood flow in pathologic myopia.PSR could not improve but might maintain the circulation of pathologic myopia eyes with posterior staphyloma.

ACKNOWLEDGEMENTS

Foundations: Supported by National Natural Science Foundation of China (No.81570891; No.81272981); the Beijing Municipal Administration of Hospitals' Ascent Plan (No.DFL20150201); Science & Technology Project of Beijing Municipal Science & Technology Commission (No. Z151100001615052); Beijing Municipal Administration of Hospitals Clinical Medicine Development of Special Funding Support (No.ZYLX201307); Beijing Natural Science Foundation (No.7151003); Advanced Health Care Professionals Development Project of Beijing Municipal Health Bureau (No.2014-2-003).

Conflicts of Interest: Mo J, None; **Duan AL,** None; **Chan SY,** None; **Wang XF,** None; **Wei WB,** None.

REFERENCES

1 Cedrone C, Nucci C, Scuderi G, Ricci F, Cerulli A, Culasso F. Prevalence of blindness and low vision in an Italian population: a comparison with other European studies. *Eye (Lond)* 2006;20(6):661-667.

2 Buch H, Vinding T, Nielsen NV. Prevalence and causes of visual impairment according to World Health Organization and United States criteria in an aged, urban Scandinavian population: the Copenhagen City eye study. *Ophthalmology* 2001;108(12):2347-2357.

3 Xu L, Wang Y, Li Y, Wang Y, Cui T, Li J, Jonas JB. Causes of blindness and visual impairment in urban and rural areas in Beijing: the Beijing eye study. *Ophthalmology* 2006;113(7):1134.e1-11.

4 Hsu WM, Cheng CY, Liu JH, Tsai SY, Chou P. Prevalence and causes of visual impairment in an elderly Chinese population in Taiwan: the Shihpai eye study. *Ophthalmology* 2004; 111(1):62-69.

5 Iwase A, Araie M, Tomidokoro A, Yamamoto T, Shimizu H, Kitazawa Y; Tajimi study group. Prevalence and causes of low vision and blindness in a Japanese adult population: the Tajimi study. *Ophthalmology* 2006;113(8): 1354-1362.

6 Ohno-Matsui K, Kawasaki R, Jonas JB, Cheung CM, Saw SM, Verhoeven VJ, Klaver CC, Moriyama M, Shinohara K, Kawasaki Y, Yamazaki M, Meuer S, Ishibashi T, Yasuda M, Yamashita H, Sugano A, Wang JJ, Mitchell P, Wong TY; META-analysis for pathologic myopia (META-PM) study group. International photographic classification and grading system for myopic maculopathy. *Am J Ophthalmol* 2015;159(5):877-883.

7 Jonas JB, Xu L. Histological changes of high axial myopia. *Eye (Lond)* 2014;28(2):113-117.

8 Chebil A, Ben Achour B, Chaker N, Bouladi M, Charfi H, EI Matri L. Factors linked to foveoschisis in high myopia. *J Fr Ophtalmol* 2014;37(2): 138-142.

9 Henaine-Berra A, Zand-Hadas IM, Fromow-Guerra J, Garcia-Aguirre G. Prevalence of macular anatomic abnormalities in high myopia. *Ophthalmic Surg Lasers Imaging Retina* 2013;44(2):140-144.

10 Ohno-Matsui, K. Proposed classification of posterior staphylomas based on analyses of eye shape by three-dimensional magnetic resonance imaging. *Ophthalmology* 2014;121(9):1798-1809.

11 Shevelev MM. Operation against high myopia and scleralectasia with aid of the transplantation of fascia lata on thinned sclera. *Russ Oftalmol J* 1930;11:107-110.

12 Thompson FB. A simplified scleral reinforcement technique. *Am J Ophthalmol* 1978;86(6):782-790.

13 Thompson FB, Turner AF. Computed axial tomography on highly myopic eyes following scleral reinforcement surgery. *Ophthalmic Surg* 1992;23(4):253-259.

14 Xue A, Bao F, Zheng L, Wang Q, Cheng L, Qu J. Posterior scleral reinforcement on progressive high myopia young patients. *Optom Vis Sci* 2014;91(4):412-418.

15 Liu XD, Lü JH, Chu RY. Long-term studies on clinical therapeutic efficiency of posterior scleral reinforcement surgery. *Zhong Hua Yan Ke Za Zhi* 2011;47(6):527-530.

16 Chu R, Jiang Y, Zhang J, Li M. Posterior scleral reinforcement operation in the high myopia with macular degeneration. *Yan Ke Xue Bao* 1990;6 (3-4):95-98.

17 Spaide RF, Klancnik JM Jr, Cooney MJ. Retinal vascular layers imaged by fluorescein angiography and optical coherence tomography angiography. *JAMA Opthalmol* 2015;133(1):45-50.

18 Yu J, Jiang C, Wang X, Zhu L, Gu R, Xu H, Jia Y, Huang D, Sun X. Macular perfusion in healthy Chinese: an optical coherence tomography angiogram study. *Invest Ophthalmol Vis Sci* 2015;56(5):3212-3217.

19 Jia Y, Wei E, Wang X, Zhang X, Morrison JC, Parikh M, Lombardi LH, Gattey DM, Armour RL, Edmunds B, Kraus M, Fujimoto JG, Huang D. Optical coherence tomography angiography of optic disc perfusion in glaucoma. *Ophthalmology* 2014;121(7):1322-1232.

20 Hayashi K, Ohno-Matsui K, Shimada N, Moriyama M, Kojima A, Hayashi W, Yasuzumi K, Nagaoka N, Saka N, Yoshida T, Tokoro T, Mochizuki M. Long-term pattern of progression of myopic maculopathy. *Ophthalmology* 2010;117(8):1595-1611.

21 Wei E, Jia Y, Tan O, Potsaid B, Liu JJ, Choi W, Fujimoto JG, Huang D. Parafoveal retinal vascular response to pattern visual stimulation assessed with OCT angiography. *PLoS One* 2013;8(12):e81343.

22 Li XJ, Yang XP, Li QM, Wang YY, Wang Y, Lyu XB, Jia H. Posterior scleral reinforcement for the treatment of pathological myopia. *Int J Opthalmol* 2016;9(4):580-584.