Original Article

Tendency for Evolution of High Myopia in 308 Chinese School Children from Xi'an City

Yanming Chen[1,*], Yining Shi[2], Le Yang[2]

1 China Medical University, Shenyang 110001, China

2 Department of Ophthalmology, Shaanxi Province People's Hospital, Xi´an 710068, China

Abstract

Purpose: To observe the refractive status, especially the tendency for evolution of high myopia, in eyes of Chinese school children from Xi'an city.

Methods: The study was conducted in 11514 eyes of the 5757 students aged between 7~18 years in Xi'an city primary and high schools. The inclusion criterion was >-6D of the spherical equivalent refraction. The object ophthalmic examinations were done, included non-cycloplegic objective refraction, visual acuity, intraocular pressure, fundus evaluation by ophthalmologists and nurses with professional training. Specially designed questionnaires were filled in and the data were statistically analyzed with SPSS10.0.

Results: Of 11514 eyes, the detection rate was 81.4% (9376 eyes) for myopia and 5.3% (615 eyes) for high myopia. High myopia was found in 2.6% (300 eyes) of right eyes, 2.7% (315 eyes) in left eyes, and 2.4% (275 eyes) were in boys and 2.9% (340 eyes) in girls. Among 12 school grades, the detection rates of high myopia increased significantly with student age, with 0.9% in the 1[st] grade of primary school and 12.5% in the 3rd year of senior middle school. The average refractive error of spherical equivalent refraction was (-7.43±1.29) D with 95% confidence interval (-7.54,-7.33). No significant differences were found between the right and left eyes or both genders. The distribution of myopic severity was lowest(-6D) in primary school students younger than 12 years, was higher (-8D) in junior middle school students older than 13 years, and highest (-13D) in senior middle school students.

Conclusion: A continuous growth was evident in the severity of high myopia throughout 12 years of primary and middle school except for the first year of primary school, with growth occurring in two transitional stages between the senior primary and junior middle school years, and between the junior and senior middle school years. The distribution of high myopia was lowest, at -6D, in primary school, increased to -8D in junior middle school, and progressed to -10D in senior middle school, indicating a high risk of development of pathologic myopia during the students' later lifespan. The adolescent period of 13 to 18 years of age in middle school is a critical period for the development of pathological myopia over -8D. (***Eye Science 2014; 29:36-42***)

Keywords: school children; high myopia; evolution

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* **Corresponding author:** Yanming Chen, E-mail: ophthal@163.com

Myopia, especially high myopia, is one of leading causes of blindness. Control of myopia development from low or moderate myopia to high myopia is important since the pathological effects are mainly seen with high myopia with a refraction error of over -8D. The complications arising from high myopia may threaten visual quality, thereby imposing a heavy socioeconomic burden on our country. Therefore, the increasingly high prevalence of myopia in the population of younger schoolchildren is worrying. A misunderstanding also exists among the public, who consider that myopia can be treated or even cured simply by wearing a pair of glasses or by laser surgery after 18 years of age. However, the essence of the pathophysiology of high myopia is overgrowth of the eyeball and consequential ocular tissue degeneration. No well-established clinical methods are available to reverse the natural course of myopic development, but early intervention may delay the pathophysiological progression of this disease. Therefore, determining the stage at which high myopia develops is key to its treatment.

Current research focuses on the clinical manifestation of late stage myopia using advanced equipment, and new treatment methods. The natural course of myopia is poorly understood. Our prevalence of myopia is about 33%[1] or more, suggesting the population in China with myopia is more than 429 million. Among these, 1.0% of patients have pathological myopia, indicating more than 3 million persons are or will be threatened with blindness. However, it takes a long time for myopia to become evident in clinics, and the clinical manifestations show complex and different features depending on patient age, refraction errors, and ocular biologic parameters. These factors complicate the collection of clinical cases to form a sufficiently large sample for longitudinal observation and to describe the underlying mechanism.

Excimer laser and orthokeratology provide psychologically satisfying results for children with myopia, so their parents may ignore the fact that the patient has myopia after these treatments. This has led to a large number of young adults being diagnosed with high myopia later in life, so that the high myopia population is now out of control. Our previous study[2] and epidemiological studies by Lin[3] suggested that the evolution of acquired myopia progressed gradually from the low to moderate to high degrees, even up to 24 years of age. Refractive compensation obscured the real growth of the eye, as explained by the concepts of hyperopic buffering in the course of emmetropion[4]. This paper will discuss the trends in the evolution of high myopia in Chinese schoolchildren.

Materials and methods

Participants: The study was conducted in 11514 eyes of the 5757 students aged from 7~18 years who attended four whole-day elementary and middle schools in Xi'an city.

Contents inspection items include: International standard vision chart, auto refractor (NIKON SPEEDY-K), auto tonometer (TOPCON CT80), slit lamp microscope (Suzhou Sixty-Six) direct ophthalmoscope (Suzhou Sixty-Six). All investigators have been engaged in clinical ophthalmologic practice for many years, and have been trained in a group with unified standards.

Diagnostic criteria: Referred to the second (2005) edition of "Chinese Ophthalmology" relevant diagnostic criteria[5], categorized as follows: refraction, hyperopia> +0.50 D, emmetropia +0.50 D ~–0.50D, low myopia–0.50D ~–3D, middle myopia –3 ~–6D, high myopia >–6D. (For consistency, we did not use the refraction classification of Wang[6] for young people, <18 years old in boys and <16 years old in girls as low myopia ≤-2.00D, moderate myopia>-2.00D, high myopia>-4.00D).

Statistical analysis

Data were entered into Microsoft Office 2003 EXCEL software to establish a database; the data were statistically analyzed with SPSS10.0. For the constituent ratio of eye refractive status, the means were analyzed separately, including boys and girls, left eye and right eye, refractive error in the low, moderate, and high myopia cases, and hyperopia and emmetropia. ANOVA analysis was used where the data showed a normal distribution, homogeneity of variance; non-parametric methods in the *Chi*-square test, Kruskal-Wallis test, and Mann-Whitney U test were used where the data showed non-normal distribution, or variance was missing.

Results

Constituent ratio of high myopia

Of 11514 eyes, the detected rate was 81.4% (9376 eyes) for myopia and 5.3% (615 eyes) for high myopia. The detected rate of high myopia, *t* was 2.6% (300 eyes) in right eyes, 2.7% (315eyes) in left eyes, 2.4% (275 eyes) in boys, and 2.9% (340 eyes) in girls.

The detected rate of high myopia increased significantly with school age, manifesting as 0.9% in the 1st grade of primary school, 1.6% in the 6th grade of primary school, 8.0% in the 3rd year of junior middle school, and 12.5% in the 3rd year of senior middle school. The average detected rates were 1.1% and 7.7% in primary school and high school, respectively. Divided at 3-year interval, the average detected rates were 0.8% in junior primary school, 1.6% in senior primary school, 4.9% in junior middle school, and 12.3% in senior middle school (Figure).

The constituent ratio was 2.4% (275 eyes) for boys and 2.9% (340 eyes) for girls. During the first 4 school years, the percentage of high myopia was higher in

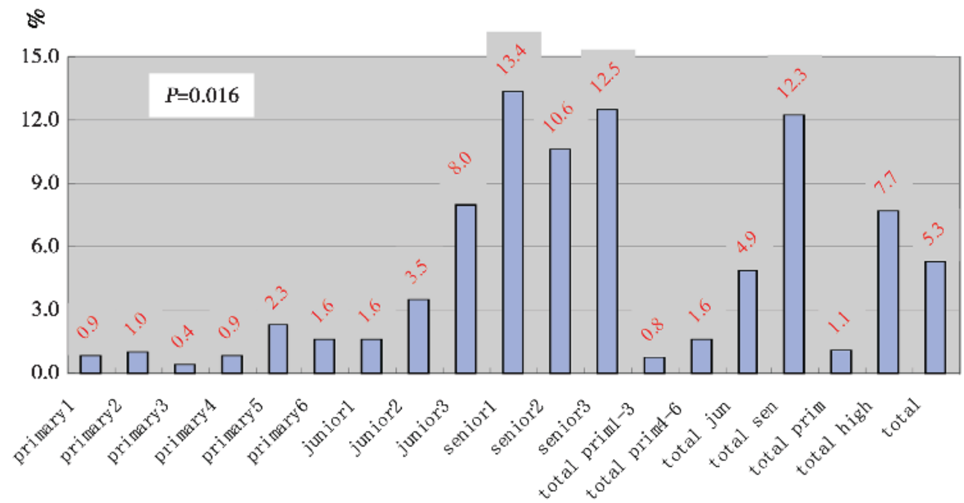
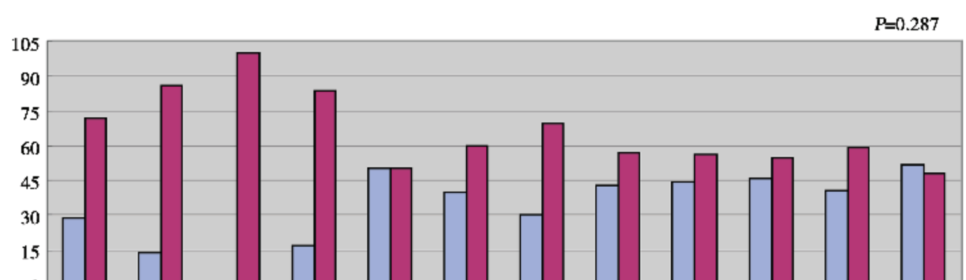


Figure 1 Constituent ratio of high myopia in different grades and stages among schoolchildren (%)

girls than in boys. As time progressed, this difference tended to disappear (P=0.287) (Figure 2).

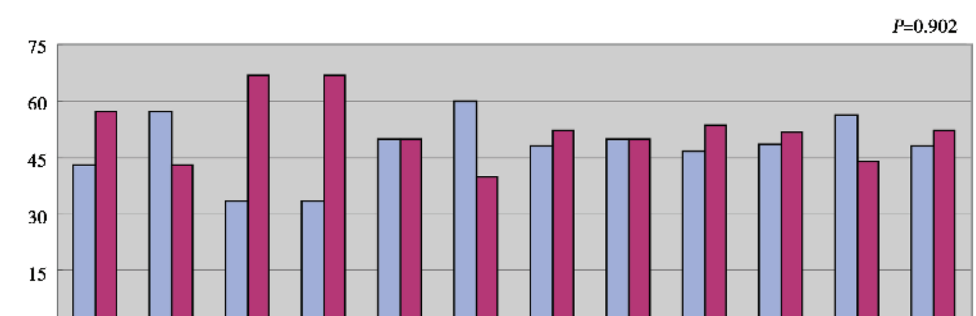
The constituent ratio of high myopia was 2.6% (300 eyes) in right eyes, and 2.7% (315 eyes) in left eyes. No significant difference were noted between both eyes, except in the first 4 school years (P=0.902) (Figure 3).

Distribution of refractive error of high myopia a-



	primary1	primary2	primary3	primary4	primary5	primary6	junior1	junior2	junior3	senior1	senior2	senior3
M%	28.6	14.3		16.7	50	40	30.4	43.2	44	45.5	40.9	52
F%	71.4	85.7	100	83.3	50	60	69.6	56.8	56	54.5	59.1	48

Figure 2 Constituent ratio of high myopia among schoolchildren of both genders (%)



	primary1	primary2	primary3	primary4	primary5	primary6	junior1	junior2	junior3	senior1	senior2	senior3
OD%	42.9	57.1	33.3	33.3	50	60	47.8	50	46.5	48.5	56.1	48
OS%	57.1	42.9	66.7	66.7	50	40	52.2	50	53.5	51.5	43.9	52

Figure 3 Constituent ratio of high myopia in different eyes among schoolchildren (%)

mong schoolchildren and the tendency of development of myopia

The average refractive error of spherical equivalent refraction was (-7.43±1.29)D with 95% confidence interval (CI) (-7.54, -7.33)D (Figure 4, Table 1).

Among the 12 school grades, these values were (-7.26±0.62)D for the 1st grade of primary school, (-6.95±0.58)D for the 6th grade of primary school, (-7.41 ±1.37)D for the 3rd year of junior middle school, and (-7.30±1.13)D for the 3rd year of senior middle school. There was a significant difference among the 12 grades (P=0.009).

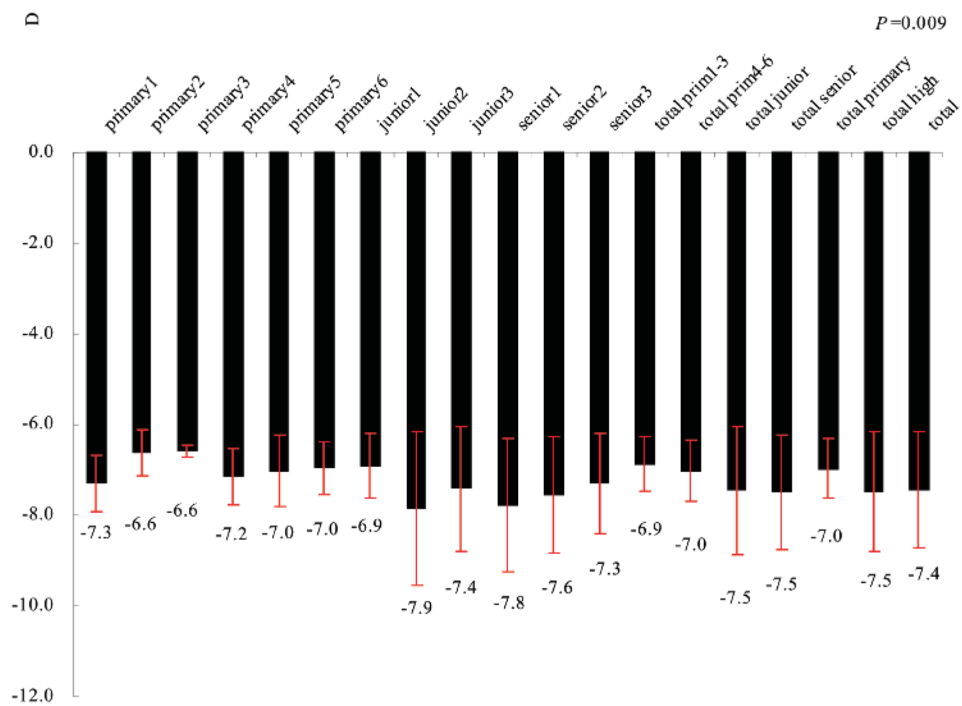


Figure 4 Distribution of average refractive error of high myopia among schoolchildren (D)

Table 1 Average refraction at different ages

Grade	Eyes(N)	Mean(D)	SD	95% Confidence Interval for mean	Min, Max
Primary1	7	-7.29	0.62	-7.85, -6.72	-8.00, -6.63
Primary2	7	-6.61	0.51	-7.08, -6.13	-7.50, -6.13
Primary3	3	-6.58	0.14	-6.94, -6.22	-6.75, -6.50
Primary4	6	-7.15	0.61	-7.79, -6.51	-7.88, -6.38
Primary5	14	-7.02	0.80	-7.48, -6.56	-8.50, -6.25
Primary6	10	-6.95	0.58	-7.37, -6.53	-7.88, -6.13
Junior1	23	-6.92	0.72	-7.23, -6.61	-8.88, -6.13
Junior2	44	-7.85	1.69	-8.37, -7.34	-12.75, -6.13
Junior3	159	-7.41	1.37	-7.63, -7.20	-16.13, -6.13
Senior1	101	-7.77	1.46	-8.06, -7.48	-12.38, -6.13
Senior2	66	-7.55	1.27	-7.86, -7.24	-11.00, -6.13
Senior3	175	-7.30	1.13	-7.47, -7.13	-12.75, -6.13
Total primary1–3	17	-6.88	0.60	-7.19, -6.57	-8.00, -6.13
Total primary4–6	30	-7.02	0.68	-7.27, -6.77	-8.50, -6.13
Total junior	226	-7.45	1.41	-7.63, -7.26	-16.13, -6.13
Total senior	342	-7.49	1.28	-7.62, -7.35	-12.75, -6.13
Total primary	47	-6.97	0.65	-7.16, -6.78	-8.50, -6.13
Total high school	568	-7.47	1.33	-7.58, -7.36	-16.13, -6.13
Total	615	-7.43	1.30	-7.54, -7.33	-16.13, -6.13

The average refractive error in the six years of primary school was (-6.97±0.6)D with 95% CI (-7.16, 6.78)D, while in middle school this value was (-7.47±1.33)D with 95% CI (-7.58, -7.36)D. The difference was statistically significant (*P*=0.011).

The average refractive error in 3-year junior and senior primary school, junior and senior middle school were (-6.88±0.60)D with 95% CI (-7.19, 6.57)D, (-7.02±0.68)D with CI (-7.27, -6.77)D, (-7.45±1.41)D with 95% CI (-7.63, -7.26)D, and (-7.49±1.28)D with 95% CI (-7.62, -7.35)D, respectively (*P*=0.000).

No significant differences were observed between the right or left eyes or between genders.

Distribution of high myopia

The severity was lower (-6D) in primary school students, higher (-8D) in junior middle school students, and highest (-13D) in junior and senior middle school students (Figure 5).

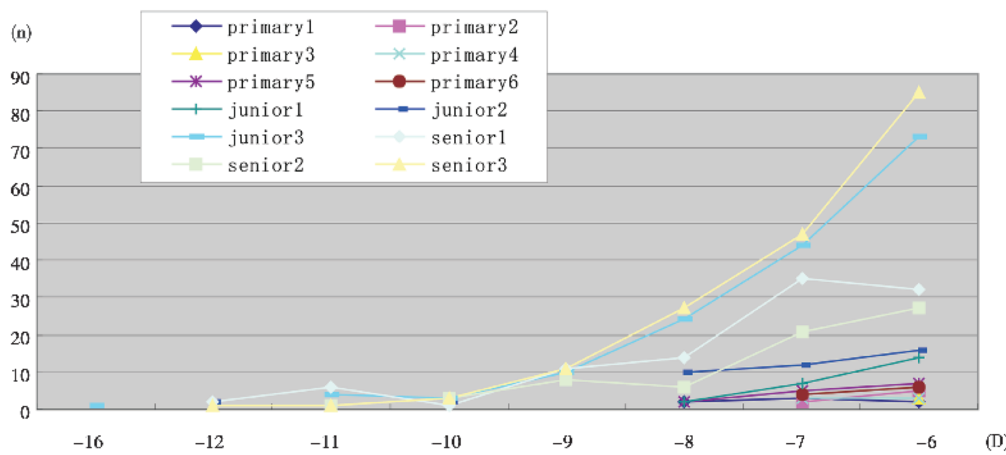


Figure 5 Distribution of high myopia among schoolchildren (eye)

Discussion

The onset of myopia at younger than 15 years of age may result in development of high myopia. This study showed that at the ages of 7~18 years, the detected rate was 81.4% for myopia and 5.3% for high myopia. The detection rate of high myopia significantly increased with increasing student age, progressing from 0.9% in the 1st grade of primary school to 1.6% in the 6th grade of primary school, 8.0% in the 3rd year of junior middle school, and 12.5% in the 3rd year of senior middle school.

The average severity of (-7.26±0.62)D in 1st grade was the same as the severity (-7.30±1.13)D in the 3rd year of senior middle school, suggesting that an earlier onset age of myopia was associated with a more severe refraction error and could develop into high myopia at the end of adolescence, thereby threatening vision. Long[7] followed up 437 cases in 1987 to observe the evolution of myopia and confirmed that development of myopia was quick among children in adolescent stages, and that young people who had developed myopia before 15 years of age were more prone to progress to high myopia.

The key age for formation of pathological myopia over -8D was during junior high school, between 13 to 18 years of age. The results also showed that the distribution of high myopia during the primary school, especially in lower grades, was close to -6D, while the distribution of high myopia during high school, particularly junior high school, crept up to -8.0D, and further progressed to -10.0D, which was pathologically significant between late junior and senior high school. These results suggested that the formation of pathological myopia may occur during junior high school at ages of 13 to 18 years.

Clinically, we used the refraction error -6D as the diagnosis criterion for high myopia. Nevertheless, 10% of the cases show no pathological changes between myopia -6D to -10D, especially in young people. Curtin mentioned in his early study that attention should be paid to the emmetropion in myopia studies involving young children, as refractive element compensation may keep the ocular refraction error within the normal range during the eyeball's early development. Another clinical problem is that the earliest fundus changes should not be ignored and treated as normal features; these would include tessellation and papillary disc tilting and crescent in the fundus, which may hint at the onset and position of posterior staphyloma, and may lead to misdiagnosis of pathological myopia as simple high myopia in childhood. More than 10 years is required for typical pathological lesions to evolve from the initial appearance in the clinical natural course, and we could barely observe typical changes clinically in children's fundi, like Fuchs' spot, subretinal choroidal neovascularization, and focal retinochoroidal atrophy, let alone the early changes of tessellation and papillary disc tilting and crescent. The further development of myopia in 18-year-old college students, studied by Lin[8], suggested that we may need to extend the follow up for the pathological changes up to 25 years of age, which would help to reveal the evolution of high myopia into pathologic myopia. The present study revealed that the key stage in the development of pathological myopia occurs after 13 years of age.

In fact, clinical studies[9] have found a tendency toward evolution of pathological myopia that involved two areas, the optic disc and macula, when the posterior segment of eyeball began to expand and caused axial elongation or stretching in the posterior pole. At the very beginning stage, the eyeball expansion initially started at the posterior pole of the optic disc and macula area. The structure of the optic disc developed a shearing force which obstructed nasal retinal and choroidal tissues (lamina vitrea complex) from shifting to the temporal side of the optic disc. The shearing caused the retinal tissue to be dragged over the nasal optic disc to the temporal side and formed the fold as a supertraction, or Weiss-Otto reflex. The optic disc then showed a tilting and the temporal crescent appeared when the RPE layer detached from the border of the optic disc. With the further excessive axial elongation, the choroidal vascular tissue could displace from the optic disc and the crescent became wider and the optic disc tilted further. The posterior pole staphyloma developed gradually. If the crescent was wider than 1PD, this was a signal that myopia may be progressing.

On the other hand, ocular expansion may stretch the retinal pigment epithelium (RPE) layer on the posterior pole and cause the RPE layer to become thinner. The thin RPE layer uncovered the subretinal capillary layer of choroidal vascular structure, which showed leopard-like changes as tessellation. Initially, mild tessellation changes appeared with vaguely choroidal vessel structures underneath and then showed moderate tessellation changes with clear exposure of the medium choroidal vessel structures, and of large choroidal vessel structures gradually during the stage of the mechanical expansion of myopic development.

A survey analysis of high myopia in middle school students by Ao[10] suggested that the major changes in high myopia were tessellation in 91.7% and the myopic crescent in 91.1%. Other research about the relationship between myopic crescent and axial length in pathological myopia[11] revealed that the myopic crescent was a helpful clinical sign of pathological changes in the initial development of myopia. Yang[12] observed 406 cases and determined that the width of the myopic crescent had a positive correlation with the axial length, indicating that the myopic crescent had a clinical significance in the progression of myopia. Nie[13] analyzed the relationship between the fundus damage of pathological myopia and degree of refractive error and suggested that degree of refractive error might be treated as a signal of pathological myopia in early periods. The criteria of a refraction error below -8.00D and an axial length of 26~28 mm or more may be included as the objectives of myopia control. These study results were consistent with ours.

Typical myopic fundus appearance was deemed as an index of pathological myopia evolving from simple high myopia. We observed the high myopia fundus, case by case and year by year, in the same period[14,15] and confirmed an evolutionary process. In the 20 to 40 year age group with -10D refractive error and 25 to 27 mm axial length, tessellation change was the main lesion in the fundus and the B-scan showed a uniform expansion in the posterior segment. In the 15 to 20 year age group and 10 to 15 year age group, with the refraction of -10D and -8.75D, respectively, and an axial length of 28mm, only leopard-like fundus changes were seen. Even the 5 to 10 year age group, with refraction -5.5D and axial length of 26 mm, showed the same changes. As we mentioned above, the tessellation changes may be regarded as indicators of pathological myopia evolving from a simple high myopia in the earliest periods in patients under 30 years of age who had -4D to -6D myopia combined with myopic crescent, a size larger than 2/3PD, and the sclera-choroidal mixed type. These features should be considered as the earliest onset of posterior staphyloma, and the initial phase of myopic choroidal degeneration.

Different standards for different ages. In the meantime, we should consider that the different ages of high myopia had different standards of myopic severity. Therefore, we may need to add a further growth of 1mm axial elongation with -3.0D myopization, which was myopic shifting, before 18 years of age, especially between age 3 and 15, 1.0D for corneal-originated refractive compensation before age 6, and -2.0D for lens-originated latent compensation between age 6 and 10. As the following criteria, patients younger than age 10 may be treated as moderate and high myopia with -2D and -4D, respectively, for maintaining emmetropia through the mechanism of the refractive matching or refractive normal distribution, and hyperopic buffering[16,17].

According to Curtin's study, the changes in pathological myopia were divided into three stages: ① the early stage, which had developmental changes such as optic supertraction or Weiss-Otto reflex, myopic temporal crescent; ② the mid-stage with age, which had mechanical expansion and typical myopic fundus appearances, like tessellation; and ③ the late stage, which was characterized by retinal-choroidal degenerations with the loss of choroidal circulation and retinal choroidal atrophy occurring over middle age.

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