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PEDIATRICS

# The efficacy and safety of modified Snyder–Thompson posterior scleral reinforcement in extensive high myopia of Chinese children

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**Abstract**
*Background* To observe the efficacy and safety of modified Snyder–Thompson posterior scleral reinforcement in extensive high myopia of Chinese children. We had a retrospective design, and included a control group of children with natural progression of high myopia.
*Methods* This study included 64 eyes in 41 Chinese children with extensive high myopia who underwent modified Snyder–Thompson posterior scleral reinforcement surgery (PSR group), and 17 eyes in 11 age- and myopia-matched children who wore spectacles (control group). The mean follow-up was 4.99±1.3 years in the PSR group and 4.48±-1.3 years in the control group. Axial length, spherical equivalent (SE), uncorrected visual acuity (UCVA), best-corrected visual acuity (BCVA) and fundus examinations were recorded before and after treatment, and complications were noted.
*Results* The mean change in SE at the end of the follow-up period was 1.5±1.44 diopters (D) and 3.02±1.57D in the PSR and control groups respectively. These changes were equivalent to an increase in axial length of 1.27±0.54 mm and 2.05±0.91 mm respectively. The PSR group showed less myopic progression and less eye elongation ($p<0.001$). A notable increase in UCVA was only found in the PSR group ($p=0.0001$). The improvement in BCVA was significantly greater in the PSR group ($p=0.0354$). There were no serious complications of PSR surgery.
*Conclusion* The modified Snyder–Thompson PSR surgery was effective and safe in controlling extensive high myopia of Chinese children.

**Keywords** High myopia · Myopic progression · Progressive myopia · Axial length · Spherical equivalent · Visual acuity · Scleral reinforcement

## Introduction

Myopia has emerged as a major public health concern, and there is striking evidence for a rapid increase in its prevalence [1]. In particular, the prevalence of myopia has rapidly increased in the past 50–60 years in developed countries in east and southeast Asia [2, 3]. In urbanized East Asia, 80 %–90 % of children finishing high school are myopic [4]. Similar changes were also reported in North America, and though probably less in Europe as well [5]. Of greatest concern is the progression to high myopia. In urban centers of East Asia, the prevalence of high myopia in children of school-leaving age [4, 6, 7] is several times higher than that in older people [8–10] and is up to 10–20 % [4]. Therefore, the gradual increase in the prevalence of high myopia in younger population demonstrates the urgent need for effective treatments of myopic disorders as well as strategies to prevent myopia.

Our understanding of the biological changes involved in myopia and extensive high myopia has substantially progressed, and has led to the development of promising approaches for prevention and treatment. Extensive high myopia involves continuous elongation of the eyeball, thinning of the sclera and localized ectasia of the posterior sclera. These changes eventually lead to varying degrees of visual deterioration in highly myopic eyes [11, 12]. Notably, axial

The authors have full control of all primary data, and we agree to allow Graefe's Archive for Clinical and Experimental Ophthalmology to review our data upon request.

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length shows the strongest correlation with refractive status, as longer eyes are more likely to be myopic than shorter eyes [13]. Therefore, controlling axial elongation during development in children may be crucial to maintain normal vision, and could offer a primary target for preventing myopia.

Scleral reinforcement was first proposed by Shevelev [14]. Later, Snyder and Thompson described a modified scleral reinforcement technique [15]. In 1978, Thompson reported a further simplification of Borley and Snyder's scleral reinforcement [16]. In our review of the literature of scleral reinforcement, it seems that there are divided opinions regarding its effectiveness of this procedure. Most of the studies observed stabilization or improvements of myopia, as well as a good safety profile of sclera reinforcement [17–23]. However, Curtin and Whitmore reported disappointing results, as their study provided no convincing proof of the safety or efficacy of scleral reinforcement [24]. Therefore, scleral reinforcement is considered to be controversial, and more studies are needed to confirm its therapeutic benefit. Accordingly, the purpose of our study is to assess the efficacy and safety of modified Snyder–Thompson posterior scleral reinforcement (PSR) in treating extensive high myopia of Chinese children.

## Materials and methods

### Participants

In this retrospective study, we identified 41 children (64 eyes) who underwent a modified Snyder–Thompson PSR (PSR group) in our clinics between May 2004 and November 2008 and who were followed up after surgery. As natural history controls, we recruited 11 children (17 eyes) who were matched for age and myopia. This group of children only wore spectacles and had not received any other treatments (e.g., contact lens, refractive surgery, or pharmaceutical therapy). All of the patients were followed up for more than 2 years and had complete data for refraction and axial length, while fundus examination was performed at least twice during the follow-up period. This study was conducted in accordance with the Declaration of Helsinki. The Ethics Committee of the Eye and ENT Hospital of Fudan University approved this study. Parents or guardians of patients aged <18 years provided written informed consent before the children underwent surgery.

Subjects diagnosed with extensive high myopia and who satisfied the following criteria were eligible for this study: myopic refractive errors≥6.0 diopters (D) and axial length≥24 mm among subjects aged<8 years old; ≥8.0 D and axial length≥25 mm among subjects aged≥8 and<12-years old; ≥10.0 D and axial length≥26 mm among subjects aged≥12 and<18 years old; and best-corrected visual acuity (BCVA) inferior to that of age-matched children. Subjects were excluded if they had another ocular disease (nystagmus, glaucoma, lens abnormality, or ocular trauma), a systemic disorder that could interfere with the interpretation of the results, or had undergone ocular surgery including laser therapy and refractive surgery.

### Procedures

The same surgeon conducted all procedures in the PSR group. The surgical procedure was a modified Snyder–Thompson PSR using a strip of homologous duramater, 6 cm long and 0.8 cm wide [15]. The buckling strips were taken from the duramater of the donor, supplied by the regional Red Cross Association for doation of human organs, after testing for potential pathogens according to the Association's approved protocols. The PSR was performed under general anesthesia, to avoid inducing orbital edema following the injection of anesthetic fluids. A temporal conjunctival incision was made approximately 2 mm from the limbus, extending from an area just nasal to the superior rectus muscle, continuing in an inferior direction to an area just nasal to the inferior rectus muscle. The lateral and inferior rectus muscles were isolated, and traction sutures were placed beneath these muscles. The sclera under equator was exposed temporally and inferiorly. After identification of the inferior oblique muscle, the duramater strip was inserted under the lateral rectus, inferior oblique, and inferior rectus muscles. It was anchored over the posterior pole just between the insertion of the inferior oblique muscle and the optic nerve, corresponding to the macular area. After positioning the strip, it was sutured to the sclera, temporal to the insertion of the superior rectus muscle and inferior to the insertion of the medial rectus muscle. After surgery, topical 0.05 % dexamethasone/neomycin eye drops were administered to the operated eyes 4 times daily for 1 month.

### Study design

Before and at the final visit after surgery, both eyes underwent examinations, which included measurement of uncorrected visual acuity (UCVA) with a standard logarithmic visual acuity chart, subjective refractive, the BCVA (ARK-700A autorefractor and SSC-330 scientific subjective refractor; NIDEK Co.,Ltd,Aichi,Japan), ocular anterior segment assessment with slit-lamp, fundus examinations under a dilated pupil, measurement of intraocular pressure (IOP) using a Canon TXF non-contact tonometer, and measurement of axial length by A-mode ultrasonography and an IOL Master (Carl Zeiss Meditec, Dublin, CA, USA). Subjective cycloplegic refraction was assessed by experienced optometrists about 30 min after administering 1 drop of tropicamide 0.5 % for 3 times with 5-min intervals. The process for refraction

was repeated in the same eye for one person. As for the axial length measurement, we took ten replicate measures of the same eye in one child, and the implausible data was ignored by the system carried by the IOL-Master. All the measurements were taken by a single observer who was blinded to the study.

### Statistics

Analyses were performed using Stata software (version 11.0; Stata, College Station, TX, USA). Visual acuity was converted to logMAR for data analysis. Numerical data are expressed as mean ± standard deviation. Changes within groups from the first visit were analyzed using paired *t*-tests or matched-pairs signed-ranks test. Comparisons between groups were performed using the group *t*-test, Wilcoxons rank-sum test or the Chi-square test. In addition, we analyzed the factors that might be associated with the axial length increase and myopic progression using regression analyses. Statistical significance was assumed for $p<0.05$.

## Results

The main characteristics of patients are presented in Table 1. The children's age at the first visit ($p=0.1898$) and the duration of follow-up ($p=0.2585$) were not significantly different between the PSR and control groups.

The extent of myopia was assessed in terms of spherical equivalent (SE) with values of 10.31±2.45D (range, 7–15.5D) and 10.12±2.27D (range, 7.25–15.25D) in the PSR and control groups respectively at the time of surgery ($p=0.9630$). The mean change in SE from the time of surgery to the end of the follow-up period was 1.5±1.44D in the PSR group, compared with 3.02±1.57D in the control group. The data showed that the surgery group had less myopia progression than the control over the study period ($p=0.0003$) (Fig. 1). In the PSR group, SE decreased between surgery and follow-up in seven eyes (15.2 %), and increased by <0.5 D in nine eyes (19.6 %) during the follow-up. By contrast, only one eye (5.9 %) showed an increase in SE of <0.5 D in the control group. The difference in mean axial length between the PSR group (26.55±1.6 mm) and the control group (26.27±0.72 mm) was not significant at the first visit ($p>0.9$). Axial length increased by 2.05±0.91 mm during the study period in the control group, versus 1.27±0.54 mm in the PSR group ($p=0.0000$) (Fig. 2). An increase in axial elongation of>2.0 mm occurred in eight eyes (47.1 %) in the control group, compared with five eyes (10.9 %) in the PSR group ($\chi^2=15.3553, p<0.001$). These data indicated that PSR limited axial extension during the study period.

The mean UCVA and BCVA were similar in the two groups at the time of surgery ($p=0.9280$ and $p=0.1924$ respectively). There were marked improvements in the BCVA in both groups at the end of the follow-up period ($p<0.01$). However, a significant increase in the UCVA was only seen in the PSR group ($p=0.0001$). Although the change in UCVA was not significantly greater in the PSR group than in the control group ($p=0.5354$), the improvement in the BCVA was significantly greater in the PSR group than in the control group ($p=0.0354$) (Fig. 3).

Finally, we sought to identify the factors that might have influenced the increase of axial length and myopic progression. The myopic progression was not correlated with the distribution of follow-up years for the PSR and control group ($p=0.7804$ and $p=0.5459$ respectively). For axial elongation, the increase was independently associated with the distribution of follow-up years for the PSR and control group ($p=0.9388$ and $p=0.0795$ respectively). Moreover, neither the axial elongation nor the myopic preogression were significantly correlated with the age at the initial visit in the control group ($p=0.5744$ and $p=0.6601$ respectively). The myopic progression was not correlated with the age at the

**Table 1** Demographic and clinical characteristics

| | PSR ($n=41$) | Control ($n=11$) |
|---|---|---|
| Age (years) | 6.50±3.23 | 7.65±3.61 |
| Range | 2.4–16.4 | 1.1–14.3 |
| Sex: *n*, (%) | | |
| Male | 25 (61.0) | 6 (54.5) |
| Female | 16 (39.0) | 5 (45.5) |
| Follow-up periods (years) | 4.99±1.3 | 4.48±1.3 |
| Range | 2.8–7.3 | 2.9–7.2 |

*PSR* posterior scleral reinforcement

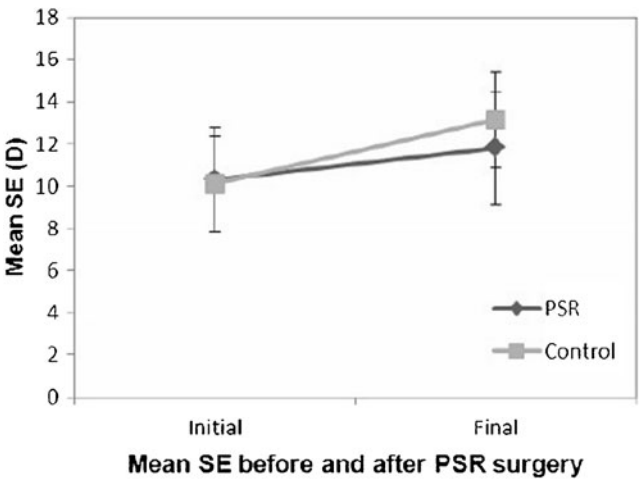


**Fig. 1** Mean SE at the initial and final visits in the PSR and the control groups. *SE* = spherical equivalent; *PSR* = posterior scleral reinforcement; *D* = diopters

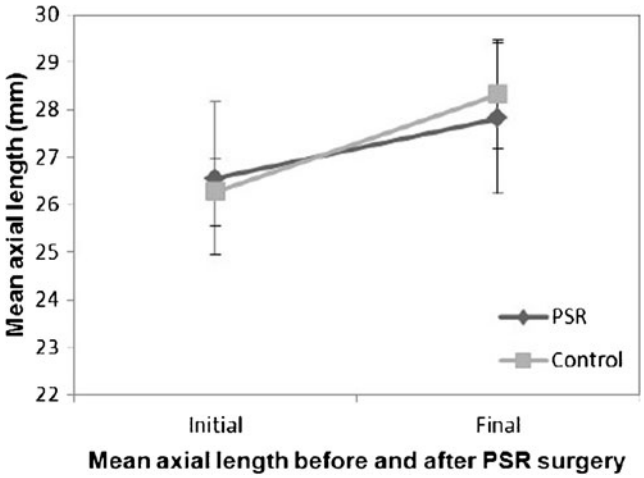


**Fig. 2** Mean axial length at the initial and final visits for the PSR and the control groups. *PSR* = posterior scleral reinforcement

initial visit for the PSR group ($p=0.0800$). The axial elongation was dependently associated with the age at the initial visit ($p=0.0471$); however, the correlation coefficient was 0.0621 and was considered as clinically insignificant.

In the PSR group, the mean IOP was 14.58±2.8 mmHg at the time of surgery and 15.57±2.96 mmHg at the end of the follow-up period, which was statistically significant ($p=0.0051$). Examination of the ocular fundus revealed no pathological signs in any eye in either group at the last visit. Conjunctival congestion and edema were found in all of the patients who underwent scleral reinforcement, and alleviated after several weeks. There were no cases of diplopia, hemorrhage, or IOP elevation. None of the eyes lost visual acuity from the surgery.

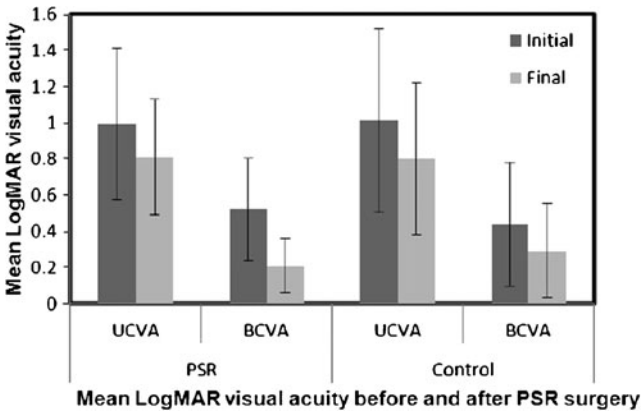


**Fig. 3** Mean LogMAR visual acuity of UCVA and BCVA at the initial and final visits for the PSR and the control groups. *PSR* = posterior scleral reinforcement; *UCVA* = the uncorrected visual acuity; *BCVA* = the best-corrected visual acuity

## Discussion

Pharmacological intervention and contact lens have been used to halt myopic progression in children with low or medium myopia. Scleral reinforcement may be the only effective method that can delay or stop the progression of high myopia, but the studies to date are controversial. Early clinical case reports revealed that reinforcement was effective in stabilizing vision, but the long-term outcomes were less favorable [15, 16, 24]. It is possible that the strengthening strips were not anchored over the posterior pole towards the macula in these early cases. Clinical experience gained after modification of the procedure has revealed favorable effects of PSR in controlling highly myopic progression and axial elongation [17–23]. However, because both eyes underwent surgery in most of the patients, there was no control group showing natural progression. Therefore, it was difficult to determine whether the procedure stabilized myopic progression [17, 19, 21]. In another study, surgery was performed in one eye, and the untreated eye served as control [20]. Nevertheless, the treated eyes were not randomized, and the eye to be supported was designated by 'patient's choice'. That choice most commonly meant that the control eye was in fact the one with the better acuity, the lower degree of myopia, or the lower historical rate of axial myopia progression. Our study had a retrospective design, but allowed comparison to a control group with natural progression of high myopia. We found that the mean axial elongation was 2.05±0.91 mm over 4.48±1.3 years in the control group, equivalent to an increase in axial myopia of 3.02±1.57D. Compared with the average axial elongation of 0.2 mm per year [20], we found a greater mean increase of almost 0.46 mm per year in untreated eyes.

Posterior staphylomas and fundus lesions are generally uncommon in childhood high myopia [25], but the incidence and severity of pathological signs in high myopia increase with age [26]. Therefore, PSR surgery has some advantages in children because it could prevent the development of degenerative lesions at an earlier age in this high-risk population. The current data support the hypothesis that PSR surgery limits eye elongation and myopic progression compared with the wearing of spectacles. In total, 16 eyes showed an increase in myopia of≤0.5D during the follow-up period in the PSR group, which indicates that this procedure stabilized the progression of myopia in these eyes. The ability to control the progression of axial myopia offers some hope of minimizing myopic macular degeneration. The mean axial elongation was almost 0.46 mm per year in the control group, compared with 0.25 mm per year in the PSR group. In addition, the degree of myopia decreased in 7/46 eyes following PSR surgery, but not in any eyes in the control group. A study by Avetisov in nine patients aged 8 to 15 years, reported stabilization (a change of 2 D or less

over follow-up) in 651 cases (72 %) at 7 years post-surgery [18] which was consistent with our results of 70.3 % in 45/64. A study by Gerinec of 20 patients with an age range of 8 to 18 years reported a change of 1.28 D with a mean follow-up of 4 years (−10.96 D pre-surgery vs –12.24 D post-surgery) which was in agreement with a increase of 0.3D per year in our study [19]. Only a few studies have reported on changes in axial length post-surgery. Gerinec reported an increase of 0.20 mm per year in axial length with a mean follow-up of 3 to 5 years [19], which was 0.25 mm per year in the current study. However, Curtin reported a mean change in refraction from baseline to end of follow-up of 0.77 D in 23 cases (compared to 0.71 D in 20 controls) over a period of 8 years, and no overall significant differences were observed between cases and controls in axial elongation [24]. In Curtin's study, only 74 % of cases were aged 8 to 18 years (average age 11 years). The high variablity in patient baseline characteristics across these trials may account for the difference.

Unlike age-related deterioration in visual acuity in adults with progressive myopia, children with high myopia showed an improvement in BCVA during the follow-up period in both groups, which was probably due to the on-going visual development in children. Notably, the PSR group showed improvements in both UCVA and BCVA. In addition, the improvement in the BCVA was significantly greater in the PSR group than in the control group. Laboratory studies revealed that scleral reinforcement towards the fovea could improve the microcirculation within the macula [27, 28], which may explain the greater improvement in the BCVA in the PSR group. It was also reported that PSR with or without pars plana vitrectomy is an effective treatment for highly myopic patients with macular retinoschisis, and might help to maintain central vision and prevent complications [20, 29, 30]. Thus, it is clear that PSR surgery strengthens the macular structure. Although the change in IOP from before surgery to the end of the follow-up period was statistically significant in the PSR group, we considered that the change was clinically insignificant.

A limitation of this study was our inability to enroll more patients in the control group. Generally, children who did not want to undergo PSR surgery were followed up at outpatient clinics with medical records kept by themselves. Though a large number of highly myopic children were seen in our department, their incomplete medical records prevented us from including them in the control group. Moreover, parents and doctors generally consider every possible method to control myopic progression in their children, which may account for the gap in the natural progression of high myopia. Another reason is that the instrument used to measure axial length differed between the first and last visits. Nevertheless, it was demonstrated that the IOL Master was comparable with the A-mode ultrasonography in measuring the axial length [31]. Thus, the extension of eyeball during the follow-up period in our study was considered reliable.

Though several authors have reported unsatisfactory effects of PSR surgery, we have reported favorable outcomes of this procedure. It is noteworthy that the PSR group experienced an average of 1.5±1.44D over 4.99±1.3 years of follow-up, equivalent to an increase in axial length of 1.27±0.54 mm. Furthermore, PSR surgery limited axial extension and myopic progression compared with the natural progression in the control group.

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**Conflict of interest** No author has a proprietary or commercial interest in the materials or methods mentioned here.

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