Ophthalmol Ther (2022) 11:1493–1502
https://doi.org/10.1007/s40123-022-00519-6

ORIGINAL RESEARCH

Outcomes of Transscleral Two-Point Fixation Versus Closed Continuous-Loop Four-Point Fixation of Intraocular Lens in Subluxated Lens Secondary to Marfan Syndrome

Xiang Gao · Wenting Zhu · Jingyi Tian · Xiaolei Sun · Ziyi Ni · Gongqiang Yuan · Jingjing Zhang

Received: March 20, 2022 / Accepted: April 29, 2022 / Published online: May 20, 2022

ABSTRACT

Introduction: To compare the outcome of two different transscleral fixation approaches for posterior chamber intraocular lens (IOL) implantation, a two-point fixation of the Sensar (Allergan) or CZ70BD (Alcon) IOL and a four-point fixation of the Akreos Adapt (Bausch & Lomb) foldable IOL, for treatment of subluxated lenses in Marfan syndrome (MFS).

Methods: Fifty-three eyes of 33 consecutive patients with subluxated lenses secondary to MFS were studied. Eighteen patients with MFS (30 eyes) received two-point fixation of the Sensar (16 patients, 26 eyes) or CZ70BD (2 patients, 4 eyes) IOL, and 15 patients with MFS (23 eyes) received four-point fixation of the Akreos Adapt IOL. Preoperative and postoperative ophthalmologic examinations were performed. A primary outcome measure of postoperative complication was studied.

Results: The mean preoperative best corrected visual acuity (BCVA) in the two-point group was 0.68 ± 0.38 logarithm of the minimum angle of resolution (logMAR), and it improved to 0.30 ± 0.32 logMAR at the final follow-up ($p < 0.05$). The mean preoperative BCVA in the four-point group was 0.68 ± 0.45 logMAR, and it improved to 0.28 ± 0.28 logMAR at the final follow-up ($p < 0.05$). The BCVA results did not differ significantly between groups. The intraocular pressure was increased at the final follow-up in the two-point group ($p < 0.05$). Transscleral two-point fixation of IOL has relatively high incidences of pupillary capture of the IOL.

Conclusion: The closed continuous-loop transscleral four-point fixation of the Akreos Adapt foldable IOL is more suitable than two-point fixation of a two-haptic IOL in treating subluxated lenses due to MFS.

Keywords: Ectopia lentis; Marfan syndrome; Posterior chamber intraocular lens; Transscleral fixation

X. Gao · W. Zhu · J. Tian · X. Sun · G. Yuan (✉) · J. Zhang (✉)
Eye Hospital of Shandong First Medical University, 372 Jingsi Road, Jinan 250021, Shandong Province, China
e-mail: yuangongqiangygq@sina.com

J. Zhang
e-mail: vitreo_retina@126.com

X. Gao · W. Zhu · J. Zhang
State Key Laboratory Cultivation Base, Shandong Provincial Key Laboratory of Ophthalmology, Shandong Eye Institute, Shandong First Medical University, Shandong Academy of Medical Sciences, Qingdao, Shandong Province, China

X. Gao · J. Tian · X. Sun · Z. Ni · G. Yuan · J. Zhang
School of Ophthalmology, Shandong First Medical University, Jinan, Shandong, China

Key Summary Points

Why carry out this study?

Transscleral two-point fixation of posterior chamber intraocular lens (IOL) may increase the risk for IOL tilt for treatment of subluxated lenses secondary to Marfan syndrome (MFS).

A closed continuous-loop transscleral suture for four-point fixation of the Akreos Adapt foldable IOL has benefits of a reliable and reproducible procedure with improved anatomical and visual outcomes, reduced complications, and decreased surgical times.

What was learned from the study?

This is the first study to compare the outcome of two different transscleral fixation techniques for posterior chamber IOL replacement for treatment of subluxated lenses in MFS.

As a result of more frequent IOL capture in the two-point group, this is the first study to propose that the closed continuous-loop transscleral four-point fixation of the Akreos Adapt foldable IOL might be a simple and minimally invasive method for subluxated lens in MFS.

INTRODUCTION

Marfan syndrome (MFS) is a systemic disorder of connective tissue caused by mutation in *FBN1*, first described in 1896 by a Parisian professor of pediatrics, Antoine-Bernard Marfan [1]. A major feature of the ocular system in MFS is ectopia lentis (subluxation/dislocation of the ocular lens) [2]. A variety of surgical repair methods are available for the management of clinically significant subluxated crystalline lenses in MFS. After initial lens removal, surgical techniques for intraocular lens (IOL) implantation include in-the-bag IOL placement by using capsular tension rings [3] (i.e., < 6 clock hours of zonulysis) and placement of anterior chamber IOLs [4], iris-fixed IOLs [5], transscleral sutured posterior chamber IOLs [6], even sutureless flanged IOLs [7] in the absence of adequate capsular support (i.e., > 6 clock hours of zonulysis). However, there is a relatively high rate of postoperative complications such as corneal endothelial damage, peripheral anterior synechia, and glaucoma in anterior chamber IOL placement [8]. The scleral fixated sutured posterior chamber IOL had a more favorable outcome and lower complication rate than the anterior chamber IOL group [9]. Therefore, transscleral ciliary sulcus fixation of posterior chamber IOLs, based on the technique first described by Malbran et al. [10] in 1986, can be considered for patients with MFS.

Numerous techniques of transscleral fixation of posterior chamber IOLs have been developed, including the traditional two-point large-incision fixation of CZ70BD (Alcon) IOL and small-incision fixation of Sensar^{TM} AR40e (Allergan) IOL [11]. However, transscleral two-point fixation of posterior chamber IOLs might increase the risk for IOL tilt and the consequent pupillary capture [6, 12]. As published previously [11, 13, 14], a closed continuous-loop transscleral suture for four-point fixation of the Akreos Adapt foldable IOL has benefits of a reliable and reproducible procedure with improved anatomical and visual outcomes, reduced complications, and decreased surgical times. Thus, in this study, we estimated the outcome and complication of two different surgical methods for treatment of subluxated lens secondary to MFS: placement of a transscleral two-point fixation of the Sensar or CZ70BD IOL or a closed continuous-loop transscleral four-point fixation of the Akreos Adapt (Bausch & Lomb) foldable IOL during pars plana vitrectomy (PPV) and lensectomy.

METHODS

Participants

The study protocol was approved by the Institutional Review Committee of Eye Hospital of Shandong First Medical University (SDSY-KYY200608) and was conducted in accordance with the tenets of the Helsinki Declaration. Possible complications had been explained, and all patients provided their informed consents prior to inclusion in the examination. The inclusion criteria were patients with subluxated lens (> 6 clock hours of zonulysis) secondary to MFS, referred after genetic or cardiologic evaluation, and the margin of subluxated lens could be observed without mydriasis by slit lamp (Fig. 1). The exclusion criteria were ocular trauma, preoperative intraocular pressure (IOP) of 25 mmHg or more while receiving treatment with eye drops; scleritis; and postoperative follow-up for less than 1 month.

Intervention

All patients underwent standard preoperative and postoperative ophthalmologic examinations including measurements of uncorrected and best corrected visual acuity (VA), slit-lamp examination, measurement of IOP, and dilated indirect slit-lamp biomicroscopy. Clinical data were collected, including age, sex, best corrected visual acuity (BCVA), refractive error, IOP, and complications.

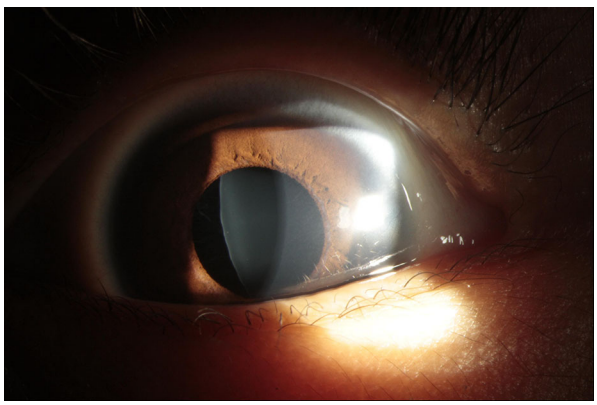

Fig. 1 Preoperative figure demonstrating the margin of subluxated lens due to MFS without mydriasis using slit lamp

Surgical Procedure

All surgeries were performed by two of the authors (JZ and GY) at the Eye Hospital of Shandong First Medical University. The four-point fixation procedure of the Akreos Adapt IOL (technique 2) (15 patients, 23 eyes) was compared with traditional two-point fixation of the Sensar (16 patients, 26 eyes) or CZ70BD (2 patients, 4 eyes) IOL (technique 1) (18 patients, 30 eyes) in MFS between August 2006 and July 2021. A PPV with lensectomy was performed using a Constellation Vision System (Alcon Laboratories, Inc, Duluth, GA) under retrobulbar anesthesia or general anesthesia in necessity for the subluxated lens. For eyes with a history of PPV, an infusion cannula was inserted into the eye to maintain the IOP at 3.5 mm posterior to the limbus of the inferotemporal quadrant.

Technique 1

After a conjunctival peritomy created generally at the 12 o'clock and 6 o'clock, blunt dissection of episcleral tissue and electric coagulation of the surgical field were performed. Transscleral passage of a straight fine needle attached to a 10-0 polypropylene suture (Ethicon, ZW 1713) was performed 1.5 mm posterior to the corneal limbus into the posterior chamber and the needle was then pulled out of the globe using the guidance of 29-gauge insulin needle along the 12 o'clock and 6 o'clock axes, leaving the 10-0 suture traversing the eye from one scleral bed to the other. A 2.65 mm clear corneal incision (CCI) according to the steep axis was made in the anterior limbus using a keratome. The anterior chamber filled with an ophthalmic viscosurgical device. The 10-0 suture was pulled out through the CCI pocket with a hook and was cut off. A foldable IOL of the Sensar AR40e (Allergan) was loaded into the Emerald C Cartridge (Lot CH00841 of AMO Inc., USA) and the cartridge was inserted into the injector. The surgeon removed the injector system and the leading haptic was kept outside of the injector. One suture end was tied at the midpoint of the

haptic (3 mm apart from the end of the haptic). Then the foldable IOL was inserted into the anterior chamber through the CCI using an injector. The trailing haptic was kept outside to prevent the IOL from falling into the vitreous cavity and tied by another suture end. The IOL was placed in the posterior chamber and the haptics were oriented into the sulcus by pulling the sutures. After achieving centration of the IOL, ends of the suture were fixed on the surface of the sclera. Five zigzag passes were done, the suture was tied onto the sclera at about 5 mm posterior to the limbus, and suture ends were cut long (> 10 mm) and buried under the rectus in all cases. The infusion cannula was removed and the conjunctival peritomy was closed.

The current strategy involves insertion of CZ70BD into the ciliary sulcus. The procedure was the same as previously described [15]. After a standard posterior infusion was placed, a toric lens marker was used to mark the corneal limbus at two points 180° apart along the horizontal axis. Each pair of nasal and temporal sclerotomies was made 2–3 mm posterior to the limbus and 2 mm apart. A 7-mm scleral tunnel incision was constructed. The suture was cut into equal halves and threaded through the eyelet of the CZ70BD IOL. Each end of the suture was pulled out of each corresponding sclerotomy using serrated forceps. The sutures were tied carefully to ensure the IOL was centered and suture tension was balanced.

The IOL used in this procedure was the Sensar AR40e (Allergan) or CZ70BD (Alcon). Sensar AR40e is a foldable three-piece hydrophobic acrylic spherical IOL with two open-loop haptics and has an optic diameter of 6.0 mm and an overall length up to 13.0 mm. The haptics of the Sensar AR40e IOL are made of polymethylmethacrylate (PMMA) and the lens is made of hydrophobic acrylic. Both materials favor mechanical stability of the IOL. The manufacturer's recommendation for *A* constant is 118.4. CZ70BD is a large-diameter optic (6.5 or 7.0 mm) one-piece PMMA IOL with large modified C-shaped haptics and has an overall length up to 12.5 mm. The manufacturer's recommendation for *A* constant is 118.8. The optic power was calculated using the SRK/T formula to achieve emmetropia.

Technique 2

The surgery was performed as previously described by Zhang et al. [13, 14]. Four sclerotomy sites were marked 2 mm from the limbus and located 3.5 mm superior and inferior to the horizontal corneal markings. A four-haptic foldable IOL of the Akreos Adapt (Bausch & Lomb) was inserted into the anterior chamber using an injector. Transscleral passage of a straight fine needle attached to 10-0 polypropylene suture (Alcon) was performed 2 mm posterior to the corneal limbus into the posterior chamber. The needle was then passed through one eyelet on the bottom-right haptic side of the IOL and pulled out of the globe using the guidance of a 29-gauge insulin needle that passed through one eyelet on the bottom-left haptic side of the IOL, leaving the 10-0 suture traversing the eye and two eyelets of IOL from bottom-right scleral bed to the bottom-left one and paralleling to the horizontal meridian. Next, the needle was pulled out subconjunctivally from bottom-left scleral fixation point to the upper-left one by a needle holder. The same procedures were repeated to introduce the fixation thread into the eye and the other eyelets of the IOL through two other scleral fixation points of the upper side. Finally, the needle was pulled out subconjunctivally from upper-right scleral fixation point to the bottom-right one by a needle holder. The suture was then looped through four eyelets on the IOL haptics and scleral fixation points. Two ends of the suture were tied on the surface of the sclera. The ends of the suture were cut and the suture knot was buried by carefully rotating it into the sclera tunnel.

The IOL used in this procedure was the Akreos Adapt (Bausch & Lomb), which is a foldable hydrophilic acrylic spherical IOL with four closed eyelets at the distal end of the haptics and has an optic diameter of 6.0 mm, an overall length up to 10.5–11.0 mm. The optic power was calculated using the SRK/T formula to achieve emmetropia. The manufacturer's recommendation for *A* constant is 118.0.

Statistical Analyses

The decimal VA was converted to the logarithm of the minimum angle of resolution (logMAR) units for the statistical analyses. Student's *t* test was used to compare preoperative and postoperative BCVA and IOP. The chi-square test was used to compare groups at each time point (preoperatively and at the final follow-up postoperatively) with regard to the percentage of eyes in the range of $\geq$ 20/40, $\leq$ 20/50, and $\leq$ 20/200. A *p* value of less than 0.05 was considered to be statistically significant. The statistical analyses were performed by using the Statistical Package for the Social Sciences program (SPSS 18.0 for Windows; Chicago, IL).

RESULTS

A total of 53 eyes of 33 patients (20 men and 13 women) with MFS were included in the study. The mean age was 19 years (range 4–54).

Visual Acuity

The two-point group contained 30 eyes of 18 patients with a mean age of 19 years (range 4–52). The mean follow-up time after implantation of an IOL was 51.7 ± 38.3 months (range 1–114). Comparison of preoperative and final postoperative BCVA of these patients showed that the mean logMAR decreased from 0.68 ± 0.38 preoperatively to 0.30 ± 0.32 at the final postoperative examination (Fig. 2). This improvement in BCVA was statistically significant ($p = 0.0001$).

The four-point group included 23 eyes of 15 patients with a mean age of 19 years (range 5–54). The mean follow-up time after implantation of an IOL was 7.7 ± 10.8 months (range 1–37). Comparison of preoperative and final postoperative BCVA of these patients showed that the mean logMAR decreased from 0.68 ± 0.45 preoperatively to 0.28 ± 0.28 at the final postoperative examination (Fig. 3). This improvement in BCVA was statistically significant ($p = 0.0007$).

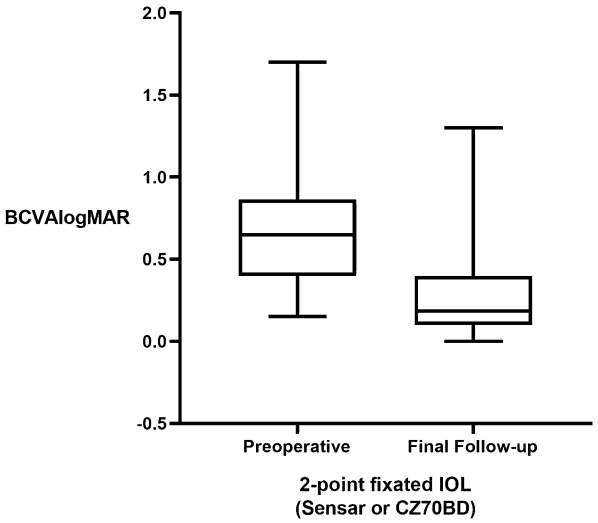

Fig. 2 Box plot of best corrected visual acuity (BCVA; logMAR) preoperatively and at the final follow-up postoperatively in the two-point scleral fixated IOL group (Sensar or CZ70BD). *logMAR* logarithm of the minimal angle of resolution

To compare the two different approaches, the percentages of eyes with BCVA $\geq$ 20/40, $\leq$ 20/50, and $\leq$ 20/200 preoperatively and at the final follow-up postoperatively were analyzed, and we found that there was no difference between groups (Table 3).

Furthermore, the proportion of all patients defined as legally blind ($\leq$ 20/200) decreased from 22.64% (12 eyes) before surgery to 7.55% (4 eyes) after surgery. Of the four eyes with a BCVA $\leq$ 20/200 at the final follow-up, one had a choroidal neovascularization at the fovea, one had severe amblyopia, and the other two suffered from a secondary glaucoma.

Intraocular Pressure

For the two-point group, compared with a mean preoperative IOP of 13.8 ± 3.8 mmHg, IOP was 16.0 ± 4.3 mmHg at the final follow-up. This IOP elevation was statistically significant ($p = 0.04$). For the four-point group, compared with a mean preoperative IOP of 15.3 ± 3.1 mmHg, IOP was 15.0 ± 3.0 mmHg at the final follow-up ($p = 0.74$).

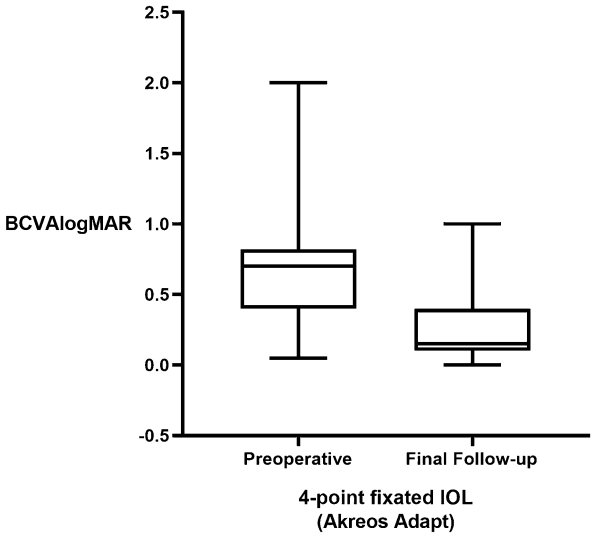

Fig. 3 Box plot of best corrected visual acuity (BCVA; logMAR) preoperatively and at the final follow-up postoperatively in the four-point scleral fixated Akreos Adapt IOL group. *logMAR* logarithm of the minimal angle of resolution

Complications

Complications in the two-point group included IOL capture (n = 11, Fig. 4), secondary glaucoma (n = 2), rhegmatogenous retinal detachment that was successfully repaired (n = 2), IOL pigment deposition (n = 2), suture exposed (n = 1), and choroidal neovascularization at the fovea (n = 1). In 11 eyes with iris capture by the IOL, the iris capture was recovered by coroplasty in one eye and a miotic agent was used in other 10 eyes to prevent recurrence.

In the four-point group, no IOL capture, suture erosion, suture loosening, hypotony, scleral atrophy, chronic inflammation, or retinal tear and/or detachment was observed in any patients. The IOLs were well centered within the follow-up period (Fig. 5). It is worth noting that both eyes of a patient with MFS in the four-point group had corneal endothelial decompensation before operation, one of which received corneal endothelium transplantation 3 months after IOL implantation and achieved a BCVA of 20/100 at the final follow-up, with mild edema and scattered pigmented keratic precipitates appeared on the corneal graft.

Table 1 Comparison of the percentages of eyes with a BCVA $\geq$ 20/40, $\leq$ 20/50, and $\leq$ 20/200 preoperatively and at the final follow-up postoperatively between two-point fixated IOLs (Sensar or CZ70BD) and four-point fixated Akreos Adapt IOLs

Range	Two-point fixated sensar or CZ70BD IOLs, total (%)	Four-point fixated akreos adapt IOLs, total (%)	*p* value
Preoperative			
$\geq$ 20/40	4 (13.33%)	5 (21.74%)	0.741
$\leq$ 20/50	19 (63.34%)	13 (56.52%)	
$\leq$ 20/200	7 (23.33%)	5 (21.74%)	
Total (n)	30	23	
Final follow-up			
$\geq$ 20/40	20 (66.67%)	16 (69.56%)	0.818
$\leq$ 20/50	7 (23.33%)	6 (26.09%)	
$\leq$ 20/200	3 (10.0%)	1 (4.35%)	
Total (n)	30	23	

No patient experienced postoperative corneal decompensation, suprachoroidal hemorrhage, hyphema, chronic uveitis, or endophthalmitis in both groups during the follow-up period.

DISCUSSION

In cases of severe lens subluxation secondary to MFS, capsular tension rings may not always be applicable [16], and placement of anterior chamber IOLs had a higher complication rate and more contraindications than the posterior

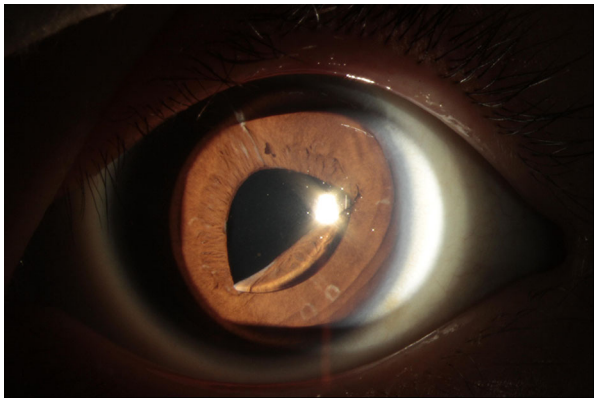

Fig. 4 Postoperative figure demonstrating pupillary capture of the IOL in two-point fixation of a two-haptic IOL in treating subluxated lens due to MFS

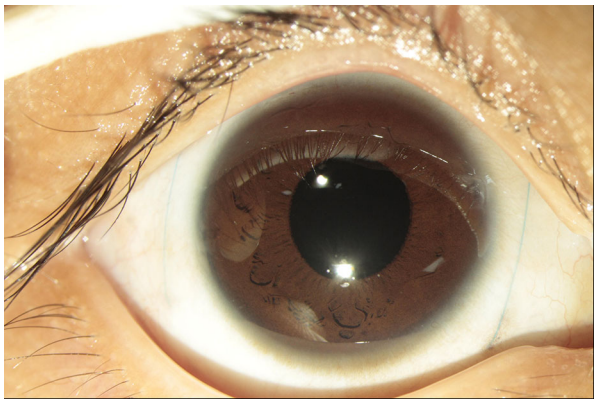

Fig. 5 Postoperative figure demonstrating four-point scleral fixation of an Akreos IOL using a closed continuous-loop suture in patients with MFS

chamber IOLs group [17], so transscleral fixation of posterior chamber IOL approach has become more advisable.

As published previously [13, 14], a closed continuous-loop transscleral suture for four-point fixation of the Akreos Adapt foldable IOL has achieved a reliable and reproducible procedure with improved anatomical and visual outcomes, reduced complications, and decreased surgical times. So in the current study, this procedure of four-point fixation of the Akreos Adapt IOL (15 patients, 23 eyes) was compared with traditional transscleral two-point fixation of the Sensar AR40e or CZ70BD IOL (18 patients, 30 eyes) in MFS between August 2006 and July 2021. The BCVA at the final follow-up improved in both groups, consistent with previous studies. Asadi and Kheirkhah [6] evaluated the long-term results of transsclerally fixated posterior chamber IOL in children without adequate capsular support, including six eyes with MFS, and demonstrated that BCVA improved postoperatively in 48% eyes by more than one Snellen line. McClellan et al. [5] described 24 eyes from 17 consecutive adult patients with surgically treated subluxated crystalline lenses, including 14 eyes (58%) with MFS, and revealed that placement of iris-sutured posterior chamber IOL at the time of subluxated lens extraction with a pars plana surgical approach yields favorable results in terms of postoperative visual outcomes and surgical complications. The main cause of legal blindness in four eyes postoperatively was coexistent retinal pathologies, amblyopia, and secondary glaucoma.

Transscleral two-point fixation of IOL has relatively high incidences of pupillary capture of the IOL. In my series of 30 eyes in the two-point group, 11 eyes displayed pupillary capture and were treated medically. No pupillary capture was seen in all cases of four-point scleral suture fixation of the Akreos Adapt IOL. In some series, pupillary capture of the IOL optic has occurred in 7.9–14.3% of cases after scleral fixated sutured posterior chamber IOL implantation [18], but patients with MFS tended to have a higher rate of pupillary capture of the IOL [19]. IOL pupillary capture is usually transient, but it might cause complications such as pupillary block with secondary glaucoma, pigmentary dispersion glaucoma and iritis as well as refractive change [20, 21]. In the current study of the two-point group, compared with a mean preoperative IOP of 13.8 ± 3.8 mmHg, IOP increased to 16.0 ± 4.3 mmHg at the final follow-up ($p < 0.05$), which might be caused by high rates of pupillary capture of the IOL. Floppy iris, pliable iris, reverse pupillary block, a larger anterior chamber depth, abnormal fluidics of aqueous humor, the IOL material, and inaccurate two-point sclerotomies are suggested as possible causes of pupillary IOL capture [22–24]. Scharioth [25] found that the most important prognostic factor for postoperative iris capture in eyes with good IOL positioning is

an intraoperative reverse pupillary block, and suggested performing a surgical iridectomy (preferably with a small-gauge vitrectome) with adding postoperative pilocarpine therapy to treat iris capture in patients with transscleral-fixated posterior chamber IOLs. In conclusion, four-point scleral suture fixation of the Akreos Adapt is more suitable than two-point fixation of a two-haptic IOL in treating subluxated lens due to MFS.

One limitation of the current study was that only VA outcomes, IOP, and complications were observed. To further compare the two surgical approaches in MFS, more comprehensive clinical data such as endothelial cell density, IOL tilt, and astigmatism need to be collected. Moreover, fewer complications in the four-point group of this study at the final follow-up were probably due to shorter follow-up time. So the small sample size and limited follow-up might have biased our results. In view of the suggestive results obtained, we are recruiting more patients with MFS and collecting more detailed clinical characteristics of patients to confirm our findings.

CONCLUSIONS

This profile demonstrated that both the transscleral two-point fixation of the Sensar or CZ70BD IOL and the closed continuous-loop transscleral four-point fixation of the Akreos Adapt foldable IOL improved BCVA at the final follow-up postoperatively. As a result of more complications in the two-point group, the closed continuous-loop transscleral four-point fixation of the Akreos Adapt foldable IOL is a good option for subluxated lens secondary to MFS.

ACKNOWLEDGEMENTS

Funding. The article, including the journal's Rapid Service Fees, was funded by National Natural Science Foundation of China (82101164), Natural Science Foundation of Shandong Province, China (ZR2020QH148, ZR2021MH074, ZR2021MH152) and Medicine and Health Science Technology Development Project of Shandong Province, China (202007021313, 202007021320).

Authorship. All named authors meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship for this article, take responsibility for the integrity of the work as a whole, and have given their approval for this version to be published.

Author Contributions. All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Xiang Gao, Jingjing Zhang and Gongqiang Yuan. The first draft of the manuscript was written by Xiang Gao and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Disclosures. Xiang Gao, Wenting Zhu, Jingyi Tian, Xiaolei Sun, Ziyi Ni, Gongqiang Yuan and Jingjing Zhang declare that they have no conflict of interest.

Compliance with Ethics Guidelines. The study protocol was approved by the Institutional Review Committee of Eye Hospital of Shandong First Medical University (SDSY-KYY200608) and was conducted in accordance with the tenets of the Helsinki Declaration. All patients provided their informed consent to participate in the study.

Data Availability. All data are available from the corresponding author upon request.

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