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Research on the Z.S. technique for 8–0 polypropylene suture in scleral fixation of one-piece intraocular lens

Shancheng Si[1,2,3†], Liu Zhang[1,2,4], Rong Yang[5†], Yanhong Li[1,2,4] and Jianhui Zhang[1,2,4*†]

Abstract

Background To introduce a new flange technique (called the Z.S. fixation technique) for 8–0 polypropylene suture in scleral fixation of a one-piece intraocular lens (IOL) and evaluate its effectiveness and safety.

Methods All surgeries were performed using two strategies. First, the Z.S. fixation technique was used to fix 8–0 polypropylene sutures to the sclera and the two haptics of a one-piece IOL, respectively. The one-piece IOL previously implanted in the anterior chamber was then relocated to the posterior chamber. Finally, the suture ends outside the sclera were cauterized into flanges and buried in the sclera. All effectiveness and safety data related to the Z.S. technique were recorded and compared.

Results The Z.S. fixation technique was employed in 16 eyes of 13 patients, with a follow-up duration of at least 6 months. Postoperative uncorrected distance visual acuity (UDVA) was greatly improved in most of the operated eyes (11/16). The mean log MAR UDVA after surgery was significantly improved compared with that before surgery (0.93 ± 0.72 vs. 1.53 ± 0.73, $P = 0.002$). IOLs in the vast majority of operated eyes (15/16) remained stable during half-year follow-up. No severe intra-/post-operative complications were observed in any of the operated eyes.

Conclusion The Z.S. fixation technique for 8–0 polypropylene suture in scleral fixation of one-piece IOL reduced surgical injuries and had ideal surgical effectiveness and safety.

Significance

What was known To date, most 10–0 polypropylene suture scleral fixation techniques required knot fixation outside the sclera, which inevitably leads to long-term complications related to 10–0 sutures, such as suture erosion, knot exposure, and late suture breakage. Therefore, some scholars began to use 8–0 polypropylene suture to perform scleral fixation for one-piece intraocular lens with specific structures, but the scope of application was very narrow.

What this paper adds We introduced a compound technique of electrocoagulation fixation and scleral flapless knotless interlaminar anchoring for 8–0 polypropylene suture, which can be applied to most one-piece intraocular lenses.

†Shancheng Si and Jianhui Zhang contributed equally to this work.

*Correspondence:
Jianhui Zhang
18065165758@163.com

Full list of author information is available at the end of the article

Keywords Scleral flapless, Interlaminar anchoring technique, Electrocoagulation fixation, Z.S. fixation technique

Background

When the lens capsule is damaged so severely that the intraocular lens (IOL) cannot be implanted in the capsule or ciliary sulcus, scleral fixation of the IOL is required [1]. However, scleral fixation of the IOL can be divided into sutureless scleral fixation [2, 3] and sutured scleral fixation [4–9]. At present, most scleral fixation methods [4–8] required knot fixation outside the sclera, no matter 10−0 or 8−0 polypropylene suture. As the complications related to 10−0 suture erosion, knot exposure and late suture breakage [7] have gradually attracted the attention of ophthalmologists, it is particularly important to introduce the technique and concept of knotless fixation. Szurman P et al. [9]. reported a kind of Z-suture knotless technique of 10−0 polypropylene suture, which perfectly solved the problem of knot exposure.

However, the 10−0 suture is too thin and easy to break or corrode [10], so it is necessary to introduce a knotless scleral fixation technique with a thicker suture. So, we introduce a new compound technique (which we called "Z.S. fixation technique" or "Z.S. technique" below, using acronym on their surnames of the two main designers, Jianhui Zhang and Shancheng Si, to name this technique) for 8−0 polypropylene suture to overcome the shortcomings of 10−0 suture itself. Our Z.S. technique replaced the suture knot fixation method with a perfect combination of flange fixation of one-piece IOL haptic, application of 8−0 polypropylene suture, and scleral flapless knotless interlaminar anchoring technique during the entire operation procedure.

Methods

Study design and population

The data of 13 consecutive patients (16 eyes) who underwent our Z.S. fixation technique for 8−0 polypropylene suture in scleral fixation of a one-piece IOL, with a post-operative follow-up duration of at least 6 months, were retrospectively analyzed between May 2020 and June 2022. Age, sex, indications for IOL implantation, other diseases of the eye, refractive status, uncorrected distance visual acuity (UDVA), best-corrected visual acuity (BCVA), post-operative positions of implanted one-piece IOLs using swept-source optical coherence tomography (CASIA2, Tomey Corp., Nagoya, Japan), intraocular pressure (IOP), operation time, suture size, additional surgical tips or techniques, and any intra-/post-operative complications together with corresponding management were retrospectively collected. The primary objective was to observe changes in visual acuity six months after one-piece IOL implantation. The secondary objective was to observe short-term and long-term complications. Complications occurring within 1 month after surgery were defined as short-term complications, whereas long-term complications were defined as complications that occurred more than 1 month after the procedure [7]. Transient ocular hypertension was defined as an IOP of more than 21 mmHg [8].

This study was approved by the Institutional Review Board of Fuzhou Eye Hospital and was conducted in accordance with the tenets of the Declaration of Helsinki (approval No. FZYKYY-KY-2022-001). Informed consent was obtained from all subjects and/or their legal guardian(s). Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

Surgical procedures

All surgeries were performed under retrobulbar anesthesia by one of us (Z.J.)

Based on these two strategies. The main difference between strategy 1 (Fig. 1) and strategy 2 (Fig. 2) was the tools were used for the transscleral tunnel puncture. The 30G needle of a 1 ml Insulin syringe was selected for strategy 1, while an arc-shaped needle with 8−0 polypropylene suture at the tail was used for strategy 2. The detailed surgical procedures for the two strategies are as follows:

Strategy 1 (see video, which demonstrates surgical procedures)

A 2.4–2.8 mm incision was made at the 10 o'clock position of the clear cornea. The anterior chamber was filled with a viscoelastic substance. A foldable one-piece IOL was implanted into the anterior chamber through a pre-made corneal incision, and then the 8−0 polypropylene suture was guided by its needle into the inferior haptic of the IOL, with the pierced point of the haptic 1.5–2 mm away from the end of the haptic (Fig. 1A and B). The needle was cut off and then the broken suture end was cauterized into a flange with a monopolar coagulation device to prevent slippage from the haptic (Fig. 1A and B) according to the method we reported earlier [10]. The first transscleral tunnel puncture (Fig. 1A and B) at the 6 o'clock position (or other pre-designed clock positions) of the pars plana 1.5–2.0 mm posterior to the limbus was performed with a 30G needle of 1 ml insulin syringe. The 8−0 polypropylene suture was guided into the transscleral tunnel using a 30G needle. The second transscleral tunnel puncture at the 12 o'clock position (or other clock positions symmetrical with the first pre-made transscleral tunnel puncture) of the pars plana was performed with the same 30G needle after the second 8−0 suture

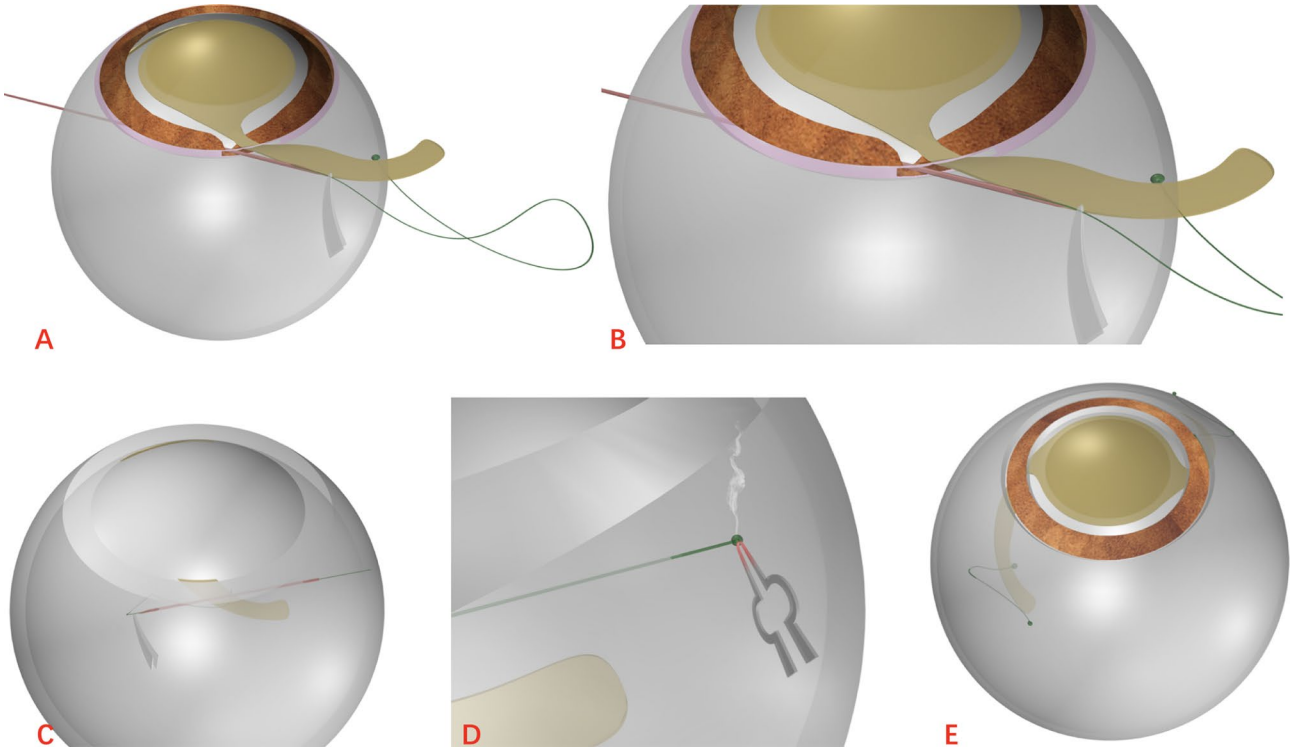

Fig. 1 Schematic diagram of key steps in the Z.S. fixation technique (Strategy 1). (**A**, **B**) The transscleral tunnel puncture at a pre-designed clock positions of the pars plana 1.5–2.0 mm posterior to the limbus with a 30G needle of a 1 ml insulin syringe, guiding the 8−0 polypropylene suture into the transscleral tunnel. (**C**) Intrascleral tunnel puncture around the pre-transscleral puncture point using the same 30G needle, guiding the suture end outside the sclera into the intrascleral tunnel. (**D**) Electrocoagulation for suture end guided out from the intrascleral tunnel, cauterizing suture ends into a flange. (**E**) Final rendering of the scleral flapless knotless interlaminar anchoring technique

was secured into the upper haptic of the IOL using the same method described above. The second suture was guided into the second transscleral tunnel. The one-piece IOL was then relocated to the posterior chamber. Finally, the two broken ends of 8−0 sutures outside the sclera were guided into the intrascleral tunnels (Fig. 1C) around 6 and 12 o'clock points by the same 30G needle respectively, then cauterized into flanges (Fig. 1D) and buried in the sclera respectively. The combination of transscleral and intrascleral tunnel punctures firmly anchored the suture to the sclera (Fig. 1E). The bulbar conjunctival flaps were sutured. When applying this strategy 1, sometimes bulbar conjunctival flaps may not be made in order to be more minimally invasive.

Strategy 2

A 2.4–2.8 mm incision was made and a foldable one-piece IOL was implanted into the anterior chamber based on strategy 1. The bulbar conjunctival flaps were made at 6 and 12 o'clock points (or two other pre-designed symmetrical clock positions) of the limbus. Then, an arc-shaped needle with 8−0 polypropylene suture at the tail was used for the first transscleral tunnel puncture at the first pre-designed clock point of the pars plana 1.5–2.0 mm posterior to the limbus (Fig. 2A) and was guided out of the pre-made corneal incision by the 26G needle of a 1 ml syringe (Fig. 2B). Electrocoagulation fixation of IOL haptics and polypropylene sutures was carried out according to the method we previously reported (Fig. 2C) [10]. The first intrascleral tunnel puncture was performed around the first pre-designed clock position, guiding the broken suture end outside the sclera into the intrascleral tunnel (black arrow in Fig. 2C) by another thinner 30G needle of a 1 ml insulin syringe. The second transscleral tunnel puncture was performed in the second position, symmetrical with the first pre-made transscleral tunnel puncture point, followed by the suture fixed to the other IOL haptic, as shown in Fig. 2C. Subsequently, the one-piece IOL was relocated to the posterior chamber. The second intrascleral tunnel puncture was performed around the second transscleral puncture point after the broken suture end outside the sclera was inserted into the 30G needle of a 1 ml syringe (Fig. 2D). Thus, the suture was introduced into the intrascleral tunnel. The redundant sutures outside of the two intrascleral tunnels were cut off, and then the broken suture ends were cauterized into flanges using a unipolar electrocoagulation device (Fig. 2E). The bulbar conjunctival flaps were closed using the same electrocoagulation device (Fig. 2F).

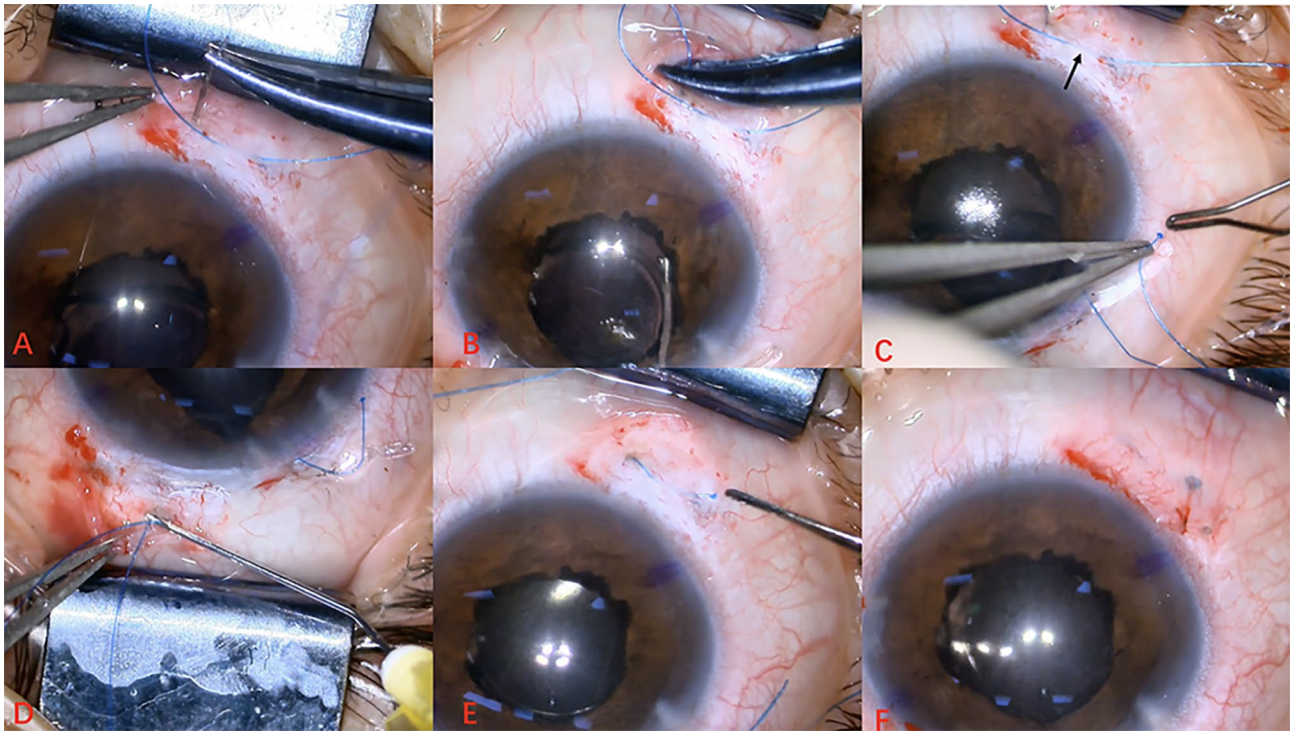

Fig. 2 Detailed surgical steps of the Z.S. fixation technique (Strategy 2). (**A**) Transscleral tunnel puncture at the pre-designed clock point of the pars plana 1.5–2.0 mm posterior to the limbus, by the arc-shaped needle with 8 – 0 polypropylene suture at the tail. (**B**) 8 – 0 polypropylene suture extraction, following its arc-shaped needle, out of the pre-made corneal incision using the 26G needle of a 1 ml syringe. (**C**) Electrocoagulation fixation of the IOL haptic. (**D**) Intrascleral tunnel puncture around the transscleral puncture point with the 30G needle of a 1 ml syringe. (**E**) Cauterization of the end of the suture to create the flange using a unipolar electrocoagulation device. (2 F) Electrocoagulation closure of the bulbar conjunctival flaps

Statistical analysis

All calculations were performed using SPSS Statistics for Windows software (version 25.0, IBM Corp.). Continuous variables were recorded as means and standard deviations (mean ± SD) or medians (interquartile range, IQR/range) according to whether the data were normally distributed, and categorical variables as counts and percentages. The Shapiro-Wilk test was used to check the normality of the data. The UDVA and BCVA were converted to the logarithm of the minimum angle of resolution (log MAR) units for analysis. For BCVA of counting fingers or worse, the following conversion was used: counting fingers, 2.0 log MAR; hand movements (HM), 2.3 log MAR; light perception, 2.6 log MAR and no light perception, 2.9 log MAR [11]. Student's t-test was used to compare continuous variables if appropriate; linear regression analysis to compare pre-/post-operative visual acuity. Statistical significance was defined as a 2-sided P value <0.05.

Results

Baseline characteristics and effectiveness data of all 16 eyes undergoing Z.S. technique

Finally, 16 eyes (6 right eyes and 10 left eyes) of 13 patients (9 men and 4 women) with a mean age of (57.06 ± 10.99) years received IOL implantation based on strategy 1 or 2, with an average operation time of (44.8 ± 13.9) minutes and each eye was followed up for at least 6 months during the 26-month study period. The reasons for poor vision within 1 week after surgery included intravitreal sterilized air tamponade (1 eye, 6.25%) and intravitreal triamcinolone acetonide injection (1 eye, 6.25%); however, the causes of poor long-term vision after surgery were amblyopia (3 eyes, 18.75%), restricted strabismus secondary to thyroid-associated ophthalmopathy (1 eye, 6.25%), traumatic leukoplakia (1 eye, 6.25%), and macular edema secondary to epiretinal membrane (1 eye, 6.25%). Baseline characteristics of the 16 eyes undergoing the Z.S. fixation technique are summarized in Table 1.

Postoperative UDVA was greatly improved in most of the operated eyes (11 eyes, 68.75%). The mean log MAR UDVA after surgery was significantly improved compared with that before surgery (0.93 ± 0.72 vs. 1.53 ± 0.73, $P=0.002$). However, there was no statistical difference between post- and pre- log MAR BCVA (0.64 ± 0.53 vs. 0.90 ± 0.82, $P=0.102$), as well as between post- and pre-astigmatism (1.18 ± 0.97 vs. 1.06 ± 0.95, $P=0.747$). The effectiveness data for the Z.S. fixation technique are summarized in Table 2.

Table 1 Baseline characteristics of all 16 eyes from 13 subjects undergoing Z.S. fixation technique

Variables	
Age (*n* = 13), years	57.06 ± 10.99
Female (*n* = 13)	4 (30.77)
Right eye (*N* = 16)	6(37.50)
Surgery duration (*N* = 16), minutes	44.8 ± 13.9
Additional Surgical Tips or Techniques (*N* = 16)	
Intraocular perfusion use	7(43.75)
Anterior vitrectomy	7(43.75)
Astigmatism correction intraocular lens use	2(12.50)
Pupiloplasty	2(12.50)
IOL scleral fixation plus sterilized air tamponade	1(6.25)
Complete vitrectomy plus epiretinal membrane removal	1(6.25)
Lensectomy due to lens subluxation	1(6.25)
Reasons for performing IOL scleral fixation (*N* = 16)	
Aphakic state	11(68.75)
IOL subluxation	4(25.00)
Traumatic lens subluxation	1(6.25)
Reasons for poor vision within postoperative 1 week (*N* = 16)	
Intravitreal sterilized air tamponade	1(6.25)
Intravitreal triamcinolone acetonide injection	1(6.25)
Reasons for poor long-term vision improvement (*N* = 16)	
Amblyopia	3(18.75)
Restricted strabismus secondary to TAO	1(6.25)
Traumatic leukoplakia	1(6.25)
Macular edema secondary to epiretinal membrane	1(6.25)

IOL = intraocular lens; TAO = Thyroid associated ophthalmopathy

Data were presented as mean ± standard deviation, median (range) or no. (%)

In the analysis of the effectiveness of the Z.S. fixation technique, the results of linear regression showed that postoperative UDVA was significantly correlated with preoperative UDVA (R^2 = 0.38; P < 0.011). In addition, postoperative BCVA was also correlated significantly with preoperative BCVA (R^2 = 0.48; P = 0.0027) (Fig. 3). In addition, the post-operative positions of five implanted one-piece IOLs were observed using swept-source optical coherence tomography, and the results showed that each IOL eccentricity was less than 0.5 mm and each IOL tilt was less than 10° (Fig. 4).

Surgical indications

The most common indication for IOL implantation was an aphakic state (11 eyes, 68.75%), followed by IOL subluxation (four eyes, 25.00%) and traumatic lens subluxation (one eye, 6.25%). Only one elderly male patient underwent his first-time IOL implantation due to traumatic lens subluxation and secondary glaucoma. We performed a vitrectomy combined with lensectomy and implanted a one-piece IOL using our new technique (Strategy 1). After surgery, the patient's UDVA improved to 20/20 from the pre-operative HM, and the IOP also returned to the normal range, without any intra-/post-operative complications related to the new technique. All surgical indications involved in Z.S. fixation technique are summarized in Table 1.

Additional surgical tips or techniques

Intraocular perfusion and anterior vitrectomy were the two most commonly combined additional surgical techniques, each of which had been used seven times (seven eyes, 43.75%). The second was astigmatism correction IOL and pupiloplasty, each of which had been used twice (two eyes, 12.50%). The least three additional surgical techniques applied in our study included IOL scleral fixation plus sterilized air tamponade, complete vitrectomy plus epiretinal membrane removal, and lensectomy due to lens subluxation plus toric IOL scleral fixation, each of which was used once (1 eye, 6.25%). Additional surgical tips and techniques combined with the Z.S. fixation technique are summarized in Table 1.

Table 2 Effectiveness and safety of Z.S. fixation technique

Variables	*N*	Pre-operation	Post-operation	*P*-value
logMAR UDVA	16	1.53 ± 0.73	0.93 ± 0.72	0.002*
logMAR BCVA	16	0.90 ± 0.82	0.64 ± 0.53	0.102
Astigmatism	11	1.06 ± 0.95	1.18 ± 0.97	0.747
Intra- / Post- operative complications (*N* = 16)				
peripheral retinal tear at 12 o'clock	1			
Transient ocular hypertension	1			
Mild vitreous hemorrhage	1			
Vitreous incarceration plus irregular pupil	1			
Pigmented glaucoma	0			

MAR = minimum angle of resolution. * = P < 0.05

Data were presented as mean ± standard deviation. P < 0.05 was considered to be statistically significant

Visual acuity outcome measures were converted into logMAR values for statistical analysis. Transient ocular hypertension was defined as an IOP of more than 21 mmHg. Z.S. fixation technique means the perfect combination of electrocoagulation fixation of one-piece IOL haptic, application of 8 − 0 polypropylene suture and scleral flapless knotless interlaminar anchoring technique

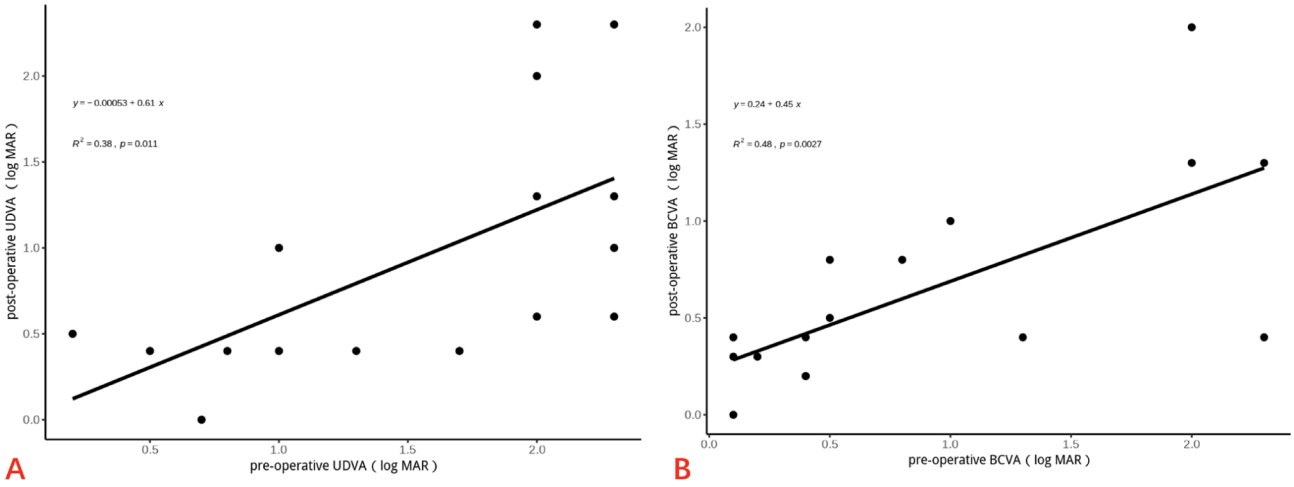

Fig. 3 Scattergraph comparing pre-/post-operative UDVA and BCVA by linear regression. The effectiveness analysis of the Z.S. fixation technique by linear regression showing (**A**) significant correlation between postoperative UDVA and preoperative UDVA ($R^2 = 0.38$; $P < 0.011$), as well as (**B**) between postoperative BCVA and preoperative BCVA ($R^2 = 0.48$; $P = 0.0027$)

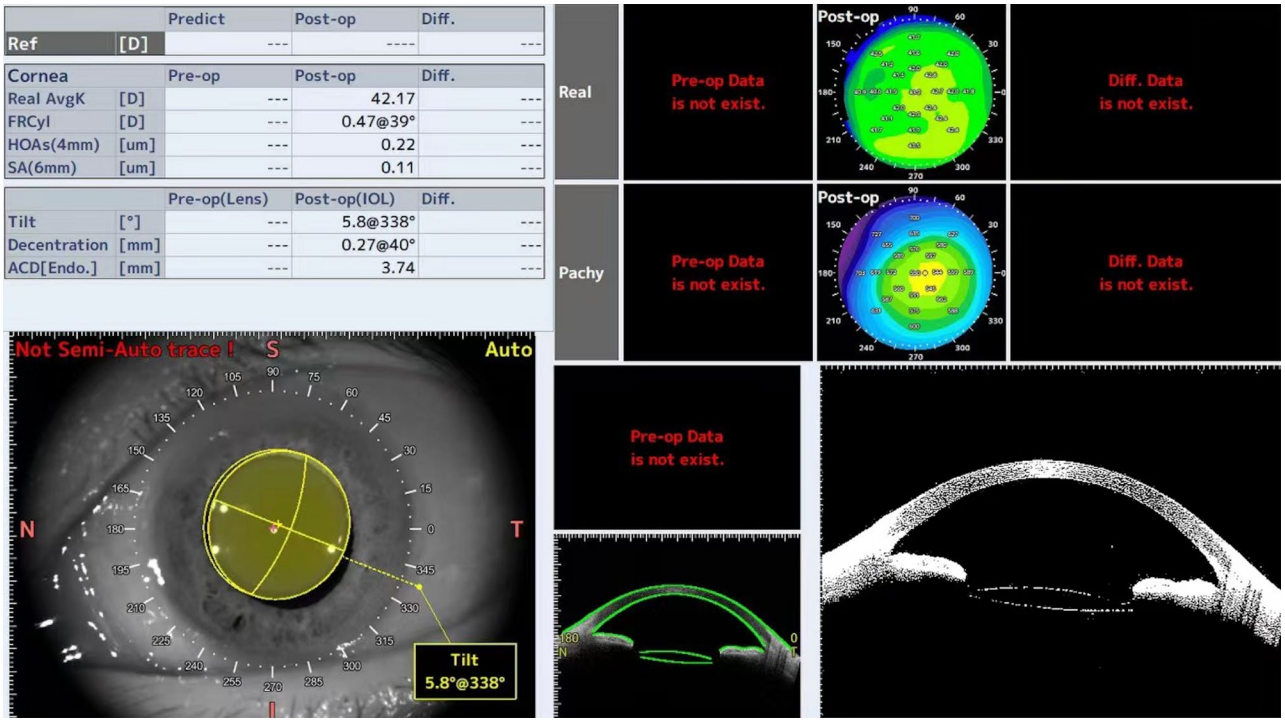

Fig. 4 Post-operative 1-week swept-source optical coherence tomography (CASIA2, Tomey Corp., Nagoya, Japan) of a 56-year-old male patient using the Z.S. fixation technique showing IOL eccentricity and tilt of 0.27 mm and 5.8°, respectively

Intra-/post- operative complications

None of the patients experienced intraoperative complications, such as suture breakage etc. that was common when applying the 10−0 suture. Only one patient had a peripheral retinal tear at the 12 o'clock position during the surgery and underwent the IOL scleral fixation plus sterilized air tamponade (one eye, 6.25%). However, three subjects each developed one of the following three postoperative complications: transient ocular hypertension (one eye, 6.25%), mild vitreous hemorrhage (one eye, 6.25%), and vitreous incarceration plus irregular pupil (one eye, 6.25%). The two subjects with the first two complications recovered spontaneously within 1 week, but the third subject (a middle-aged male) did not. The patient underwent the new technique due to traumatic hyphema plus aphakia; however, he developed vitreous incarceration on the 1st postoperative day, followed by an irregular pupil under anterior vitreous traction in

the 1st postoperative month. We had to cut off the incarcerated vitreous fiber using a yttrium aluminium garnet laser for him. After the laser treatment, with the affected eye showing a round pupil, his UDVA returned to 20/30 from HM. Except for this patient, none of the patients who received the new technique experienced severe complications such as suture loosening, suture breakage, hypotony, chronic inflammation, infective endophthalmitis, and pigmented disseminated glaucoma etc. which required additional eye surgery. The safety data for the Z.S. fixation technique are summarized in Table 2.

Discussion

In our study, it was found that among all the population who received secondary IOL implantation, men accounted for a higher proportion, with an average age of about 60 years, similar to previous literature reports [7, 8]. As for the selection of suture, 10−0 suture was often used for scleral fixation of IOL in the early stage [4, 5]. However, as time went on, the complications related to too thin/degradable 10−0 polypropylene suture such as suture erosion and fracture became more and more prominent [12–15]. Therefore, more and more scholars advocated to use 8−0 polypropylene suture/Gore-Tex Teflon suture to perform scleral fixation of IOL to overcome the disadvantages of 10−0 suture itself [6–8]. Subsequently, too thick 8−0 suture formed too large knot, which led to subsequent suture exposure and knot related infection [16]. In order to reduce the adverse outcomes related to the suture knot, ophthalmologists had to make additional scleral flap, scleral groove or tunnel to wrap the too thick suture knot, which increased the operation time and new trauma [7]. So, Z.S. fixation technique came into being. The technique we designed could not only reduce the complications associated with sutures and knots, but also increase the stability of IOL scleral fixation.

In addition, if the patient was previously implanted with a one-piece IOL, the new technique did not need to replace it with a three-piece IOL, which reduced the surgical injuries, saved the operation duration, and had similar surgical effectiveness and safety as traditional three-piece IOL scleral fixation with polypropylene non-absorbable 10−0 suture. Finally, this technique was also applicable to the toric IOL scleral fixation due to another electrocoagulation fixation technique of IOL haptic that we proposed previously [10].

The most common cause of IOL scleral fixation in our study was aphakia (11 eyes, 68.75%), which was similar to the report by Zhang Y et al. (18 eyes, 100%),[1] but different from the report by Wang T et al., [7] which believed that the most common cause was a subluxated/dislocated lens. The traditional view is that the three-piece polymethyl methacrylate IOL was more suitable for scleral fixation because of the greater elasticity of the haptic; however, the three-piece IOL needed to be knotted and fixed with suture [17–20], which had the risk of tilt or eccentricity of IOLs due to the suture knot shift in the long term. The advantages and disadvantages of the three-piece IOL are equally prominent. It seemed that this was not the most minimally invasive choice for scleral fixation of the IOL. Most of the haptics of foldable one-piece IOL are relatively short and small, so they are often unstable when used for scleral fixation, which easily causes friction between the lens and iris, resulting in pigmented disseminated ocular hypertension or glaucoma [4].

Increase the stability of scleral fixation of one-piece IOL has always been the goal of ophthalmologists. In this study, through the improvement of three main measures, the Z.S. technique successfully overcame this problem. First, an appropriate suture was selected. 8−0 polypropylene suture was used instead of a 10−0 suture to enhance the elasticity and reduce erosion and degradation of sutures in the long term. Second, the electrocoagulation fixation technique for one-piece IOL that we proposed previously [10] is used to increase the stability of soft haptic, prevent the most important problem of tilt or eccentricity in IOL implantation [21], and prevent or reduce complications related to lens-iris friction. Third, the Z.S. fixation technique was used to reduce the exposure or infection related to suture knots.

Through the improvement of the above three main measures, the complications of scleral fixation of the one-piece IOL were greatly reduced. In the long-term follow-up of 16 eyes reported by us, pigmented disseminated glaucoma, a serious postoperative complication requiring the removal of a one-piece IOL, was not found. However, among the 19 patients observed by Wang T et al., [7] five cases (26%) presented with short-term postoperative corneal edema and three cases (16%) with transient postoperative elevated IOP, which was higher than our report (0% and 6.25%, respectively); and one case of long-term elevated IOP (5.26%) and one case of long-term macular edema after surgery (5.26%) were also reported, which was similar to our results (0% and 6.25%, respectively). In another 28 patients observed by Mo B et al., [8] ten cases (35.71%) presented with postoperative corneal edema and 8 cases (28.58%) presented with temporary postoperative elevated IOP, which was higher than the proportion reported by Wang T et al. and us. It is noteworthy that Mo B et al.'s technique resulted in 4 cases of hypotony and 2 transient mild hyphema; [8] however, our technique had no such complications, but a case of transient mild vitreous hemorrhage.

Notably, all surgeries were performed based on strategy 1 or 2, with the main difference between the two strategies of being the tools used for transscleral tunnel puncture. However, the choice of strategy 1 or 2 mainly depends on the surgical skills and habits of the surgeon. In our experience, strategy 1 has less intraocular manipulation, and long-term observation may show less loss of corneal endothelial cells; therefore, we currently use strategy 1 more. According to our observation, the haptics of the implanted one-piece IOL using this surgical technique were usually anchored at a symmetrical position (2 mm behind the corneal limbus), and the positions of the suture tail passing through the haptics were basically symmetrical (1.5–2 mm away from the end of the haptic). Postoperatively, in the five eyes observed by swept-source optical coherence tomography, each IOL eccentricity was less than 0.5 mm and each IOL tilt was less than 10°. We speculated that reasons are as follows: (1) Because the two haptics of the one-piece IOL are pierced in the symmetrical positions and the inner wall of the eyeball is an approximately regular spherical shape, the one-piece IOL will find a position where the two haptics are stressed evenly when the suture is strained. In particular, the pierced positions are left 1.5–2 mm away from the ends of the haptics, and the two extra "tails", similar to the balanced rudders at the stern, will always find a force balance position to limit the intraocular tilt of the one-piece IOL. (2) The 8−0 polypropylene suture is softer than the 6−0 polypropylene suture and the haptic of the three-piece IOL. The transscleral tunnel made using the 30G needle had a larger diameter than the 8−0 polypropylene suture. Therefore, if the 8−0 polypropylene suture is twisted, it can also self-rotate to release the tension of the suture before the final positioning and cauterization to avoid the intraocular tilt of the one-piece IOL.

To the best of our knowledge, we are the first to apply the flange technique to one-piece IOL scleral fixation with polypropylene sutures without knots and named the new compound technique "Z.S. fixation technique". The Z.S. technique is significantly different from the Yamane technique, which is mainly used for scleral fixation of three-piece IOLs, and the Canabrava technique, which is mainly used for eyes with zonular instability [22, 23]. In addition, both the Yamane and Canabrava techniques are flanged scleral fixation techniques without sutures, while the Z.S. technique is a flanged scleral technique with polypropylene sutures without knots. Most importantly, the three-piece IOL haptics used in Yamane technique, have a large curvature and hardness, often require both intraocular forceps and a guiding needle to handle the second haptic simultaneously, requiring more intraocular manipulation and a longer learning curve. To date, there is no alternative technique for toric IOL implantation in eyes with large astigmatism without capsule support and the Z.S. technique provides a preliminary trial for such eyes.

However, the Z.S. fixation technique is not set in stones and can be adjusted depending on the extent of the remaining capsule. (1) When the damage to the capsule bag is mild, in some eyes with high myopia, the space of the ciliary sulcus is too wide to stably implant the one-piece IOL in the ciliary sulcus. The one-piece IOL can then be fixed in the ciliary sulcus using the Z.S. fixation technique, so that both haptics of the IOL can be anchored in the sclera, and the back of the IOL can also be supported by the capsule bag, and the position of the IOL will be very stable after surgery. (2) When the residual capsule is greater than or equal to two quadrants, one haptic of a one-piece IOL can be implanted directly into the ciliary sulcus before the residual capsule. Only the other haptic of the one-piece IOL needs to be fixed using the Z.S. fixation technique, and the residual capsule in the optic axis need to be removed. (3) When the residual capsule is less than two quadrants, it is not sufficient to stabilize any haptic of the one-piece IOL; then, the residual capsule will be completely removed, and the one-piece IOL needs to be fixed using the Z.S. fixation technique.

Therefore, the Z.S. technique for 8−0 polypropylene suture in scleral fixation of the one-piece IOL we designed had excellent effectiveness and good safety, which is worthy of further research and discussion. However, this study still has some limitations. First, retrospective research with a small sample size inevitably produced some bias in effectiveness and safety, which needs to be further verified by prospective research with a larger sample size. Second, the observation time was still not long enough, because most of the dislocations of IOLs related to suture erosion occurred after 3– 8 years when 10–0 polypropylene sutures were used [24]. Finally, our case did not include special patients with long axis length, thin scleral wall, and multiple eye surgeries. In these extreme cases, it is still unknown whether the Z.S. fixation technique we designed is applicable. We hope to address these questions in future clinical practice.

Conclusions

This compound technique replaced the suture knot fixation method with a perfect combination of electrocoagulation fixation, 8−0 polypropylene suture, and scleral anchoring technique during the entire operation procedure, completely eliminating the complications related to the scleral flap and suture knot, and was a new attempt in the development of IOL scleral fixation. The Z.S. fixation

technique overcame most of the shortcomings of various existing scleral fixation techniques and was suitable for most one-piece intraocular lens, which is a good alternative method in most clinical cases.

Abbreviations

BCVA	Best corrected visual acuity
HM	Hand movements
IOL	Intraocular lens
IOL-CTR	IOL plus capsular tension ring
IOP	Intraocular pressure
IQR	Interquartile range
log MAR	Logarithm of the minimum angle of resolution
UDVA	Uncorrected distance visual acuity

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Author contributions
SS, LZ, and JZ conceived, planned the study, and wrote the manuscript. RY and LZ acquired the data. SS and JZ designed the technique, analyzed the data, participated in the discussion and provided the comments. SS conducted data statistical analysis of the data.

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Data availability
The data that support the findings of this study are available upon request from the corresponding author [JZ].

Declarations

Human ethics
This study was approved by the Institutional Review Board of Fuzhou Eye Hospital and was conducted in accordance with the tenets of the Declaration of Helsinki (approval No. FZYKYY-KY-2022-001).

Consent to participate
All patients have provided their informed consent to participate.

Consent to publish
All authors have read and approved the manuscript. All authors have given their consent for the publication of this manuscript.

Clinical trial number
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Eye Institute and Affiliated Xiamen Eye Center of Xiamen University, School of Clinical Medicine, Xiamen University, Xiamen 361004, China
[2]Fujian Provincial Key Laboratory of Corneal & Ocular Surface and Corneal Diseases, Xiamen, Fujian 361002, China
[3]Eye Center, Beijing Tsinghua Changgung Hospital, School of Clinical Medicine, Tsinghua University, Beijing 102218, China
[4]Department of Glaucoma, Fuzhou Eye Hospital, No.88 Liuyi South Road, Cangshan District, Fuzhou 350007, China
[5]Department of Ophthalmology, The Fifth People's Hospital of Ningxia Hui Autonomous Region, Shizuishan 753000, China

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