Original Article

Bilateral superior oblique suture extension in pediatric A-pattern esotropia

Ye Haiyun [1], Fang Wangyi [1], Cheng Chi [1], Liu Qingyu [1], Zhang Yidan [1], Li Yuan [1], Kourosh Shahraki [2], Donny W Suh [2] and Qiao Tong [1]

[1] Department of Ophthalmology, Shanghai Children's Hospital, School of medicine, Shanghai Jiao Tong University, Shanghai, China

[2] Department of Ophthalmology, Gavin Herbert Eye Institute, University of California, Irvine, CA, USA

ABSTRACT

Background: A-pattern esotropia is defined as an increase of more than 10 prism diopters (PD) divergence in down-gaze than in up-gaze. The long-term outcomes of bilateral superior oblique tendon suture extension (SOSE), a hardware-free technique, were evaluated in pediatric A-pattern esotropia with bilateral superior oblique overaction (bi-SOOA), addressing complications associated with traditional silicone spacers and tenotomy.

Methods: In this retrospective cohort study, all participants with A-pattern esotropia and bi-SOOA underwent bilateral SOSE using nonabsorbable polypropylene sutures combined with medial rectus recession. Preoperative and postoperative assessments included prism cover testing in nine gazes, fundus photography for objective torsion quantification, and grading of superior oblique overaction (SOOA).

Results: This study included 64 eyes from 32 children with a mean (SD) age of 7.0 (3.1) years and a mean (SD) postoperative follow-up of 35.2 (15.6) months (range: 8–55). The mean (SD) A-pattern esodeviation collapsed from 23.4 (7.7) PD preoperatively to 2.4 (2.3) PD postoperatively ($P < 0.001$), representing an 88.3% reduction. The mean (SD) horizontal esodeviation improved from 37.5 (10.9) PD to 1.7 (1.8) PD in primary gaze ($P < 0.001$). The mean (SD) objective fundus torsion decreased from 10.9 (2.5) degrees to 1.1 (1.4) degrees ($P < 0.001$), with no cases of torsional diplopia or vertical deviation. SOOA grades normalized from 2.8 (0.7) to 0.2 (0.4) ($P < 0.001$). No suture-related complications were observed, and alignment stability was maintained through to the final follow-up visit.

Conclusions: In pediatric A-pattern esodeviation surgery, SOSE provided biomechanical precision, anatomical preservation, and elimination of hardware-related risks. Its effectiveness in collapsing A-pattern esotropia, normalizing torsion, and achieving durable outcomes establishes it as a first-line surgical intervention for bi-SOOA. This study addresses a significant gap in pediatric ophthalmology, offering extended follow-up data and highlighting the value of minimally invasive, growth-compatible techniques in protecting visual development. Larger randomized trials with extended follow-up are needed to confirm the efficacy and safety of this procedure for A-pattern esotropia.

KEYWORDS

convergent strabismus, esodeviation, A-pattern esodeviation, superior oblique muscle, suture, spacer, torsional stability, hardware-free surgery

Correspondence: Tong Qiao, Department of Ophthalmology, Shanghai Children's Hospital, School of medicine, Shanghai Jiao Tong University, Shanghai, 200062, China. Email: qiaojoel@163.com, ORCID iD: https://orcid.org/0000-0002-3244-4541. Kourosh Shahraki, Department of Ophthalmology, Gavin Herbert Eye Institute, University of California, Irvine, CA, USA - 850 Health Sciences Rd. Irvine, California 92697. Email: kourosh.shahyar@gmail.com, ORCID iD: https://orcid.org/0000-0001-9754-2284.

How to cite this article: Haiyun Y, Wangyi F, Chi C, Qingyu L, Yidan Z, Yuan L, Shahraki K, Suh DW, Tong Q. Bilateral superior oblique suture extension in pediatric A-pattern esotropia. Med Hypothesis Discov Innov Ophthalmol. 2025 Fall; 14(3): 163-170. https://doi.org/10.51329/mehdiophthal1529

Received: 17 August 2025; Accepted: 24 September 2025

INTRODUCTION

A-pattern strabismus, characterized by a divergence increase exceeding 10 prism diopters (PD) in down-gaze compared to up-gaze, presents a complex surgical challenge when coexisting with bilateral superior oblique overaction (bi-SOOA) in pediatric esotropia [1, 2]. The etiopathogenesis of A-pattern esotropia is multifactorial, involving anomalies in orbital pulley systems, neural integrator dysfunction, and biomechanical imbalances of cyclovertical muscles [2]. Superior oblique (SO) overaction, a predominant contributor to A-pattern esotropia, induces intorsion and vertical misalignment, necessitating interventions that address both horizontal and torsional components without compromising long-term ocular motility [1, 2].

Traditional management strategies for bi-SOOA have centered on SO-weakening procedures, including tenotomy, recession, and silicone tendon expanders [3–5]. While tenotomy offers immediate weakening, it risks iatrogenic Brown syndrome, postoperative hypercorrection, and torsional instability due to disruption of the tendon's anatomical insertion [4, 5]. Tendon-extension procedures could produce a reliable SO-weakening effect and prevent undesired separation of the two cut ends. According to the extension material, tendon silicon expander and suture spacer expander were mainly used [4]. Silicone spacers, though effective in graded SO lengthening, carry inherent risks of foreign body reactions, extrusion, and peribulbar fibrosis, which is particularly problematic in pediatric patients with evolving orbital anatomy [3, 6]. Recent studies underscore these limitations, reporting silicone-associated complications in 12–18% of cases, including restricted ductions and reoperation rates due to spacer migration [7–9].

Emerging evidence advocates for suture-based techniques as a hardware-free alternative to mitigate implant-related morbidity [3, 10, 11]. The superior oblique tendon suture extension (SOSE) technique, utilizing nonabsorbable sutures, preserves the tendon's native insertion while introducing a controlled, adjustable gap between transected ends. This approach theoretically maintains the SO's physiological arc of contact, reduces torsional sequelae, and allows postoperative titration—advantages critically aligned with pediatric ocular growth dynamics [3]. Recent biomechanical models corroborate that suture spacers modulate SO tension linearly, avoiding the nonlinear force decay observed in tenotomies, thereby enhancing surgical predictability [3, 7].

Despite these advances, the long-term efficacy and safety profile of SOSE in pediatric A-pattern esotropia remain underexplored. Prior studies [5, 7], such as the comparative work by Awadein et al. [7], focused predominantly on silicone spacers vs. suture spacers, while contemporary research by Xia et al. [5] focused on graded suture lengthening. However, children's dynamic ocular growth [12] demands techniques that prioritize anatomical conservation and long-term stability, features inadequately addressed in existing literature [5, 7, 9].

This study evaluates the clinical and torsional outcomes of bilateral SOSE combined with horizontal rectus recession in pediatric A-pattern esotropia, with a mean follow-up of 35 months. By employing objective torsion quantification via fundus photography and standardized 9-gaze prism cover testing, we aimed to establish the procedure's efficacy in collapsing A-pattern deviation and normalizing versions, assess its safety in preserving torsional stability, and provide mechanistic insights into how suture-mediated tendon lengthening reconciles anatomical preservation with functional correction. Our findings seek to redefine surgical paradigms for pediatric bi-SOOA, offering a hardware-free, adaptable solution that aligns with the growing emphasis on minimally invasive, complication-sparing strabismus surgery.

METHODS

This retrospective cohort study recruited consecutive pediatric patients diagnosed with A-pattern esotropia and bi-SOOA who underwent bilateral SOSE combined with horizontal rectus recession between September 2017 and November 2023. The study adhered to the tenets of the Declaration of Helsinki and received approval from the Institutional Review Board of Shanghai Children's Hospital (Approval No: 2023R090-E01). Informed consent was obtained from all legal guardians.

We reviewed medical records of patients aged 3–16 years diagnosed with A-pattern esotropia and bi-SOOA who underwent bi-SOSE combined with horizontal rectus recession. Exclusion criteria included best-corrected visual acuity worse than 0.6 in decimal notation in the better-seeing eye, coexisting retinal pathology, prior strabismus surgery, spherical equivalent >±3 diopters (D), and axial length >24.99 mm.

Recruited individuals underwent a thorough preoperative ophthalmic evaluation. All measurements and sensorimotor examinations, both at initial evaluation and during each follow-up, were performed by a single, experienced senior ophthalmologist specializing in strabismus. Comprehensive preoperative ophthalmological examinations were measurement of best-corrected distance visual acuity using Topcon CC-100 projector Snellen visual acuity chart (Topcon; Topcon Corp., Tokyo, Japan) and detailed slit-lamp examination of the anterior segment using Zeiss slit-lamp (Zeiss SL 800, Carl Zeiss Meditec AG, Jena, Germany).

To assess refractive status and visual acuity we conducted cycloplegic refraction using 1% Atropin (Xinqi, Shenyang, China), with optical correction prescribed for ≥6 weeks preoperatively following refraction by Nidek AR-1 Autorefractor (Nidek Co., Ltd., Japan).

To assess ocular alignment, we performed prism and alternate cover testing (PACT) at 6 m and 33 cm in nine gaze positions (primary, 25 degrees up/down-gaze, 30 degrees right/left-gaze, and cardinal positions). A-pattern was defined as ≥10 PD divergence in down-gaze versus up-gaze [2], and its magnitude was calculated by subtracting the up-gaze measurement from the down-gaze measurement.

To assess ocular motility and torsion, first SOOA was graded on a standardized 9-point scale (-4 [underaction] to +4 [overaction]). Objective fundus torsion was quantified via dilated fundus photography. Torsion angle was calculated as the angle between the fovea-optic disc axis and a horizontal reference line through the disc center [6]. Subjective torsion was assessed using double Maddox rod testing.

To assess passive forced duction, intraoperative passive exaggerated traction testing (PETT) was performed to rule out restrictive etiologies (e.g., Brown syndrome) [13].

All surgical procedures were performed under intravenous inhalation combined anesthesia by a single surgeon (TQ) using a standardized protocol. She performed the suture spacer surgical approach according to Goldenberg-Cohen [3].

Considering differential diagnoses such as Brown syndrome and inferior oblique muscle paralysis, PETT was performed at the start of the surgery to rule out limiting factors and estimate the SO tension degree [13]. A radial, superonasal quadrant incision was made through the conjunctiva and Tenon's capsule to expose the sclera. After engaging the superior rectus muscle and isolating the SO tendon, a prearranged/rearranged double-armed 6-0 monofilament polypropylene suture (SURGIPRO II; Covidien, Medtronic, USA) with 4 mm interval was used, transecting the superior oblique tendon in the interval. A 4–7 mm gap was set between the tendon cut ends depending on the surgical design (Figure 1). The two cut ends were fixed by the sutures. The overlying conjunctiva incision was closed using 8-0 Coated VICRYL Plus (Polyglactin 910) Synthetic Absorbable Suture (Ethicon, Ethicon Inc., NJ, USA). For combined horizontal deviation, routine bilateral medial rectus recessions were performed simultaneously without vertical transposition. No systemic medication was used.

Postoperatively, patients were evaluated at day 1, 1 week, 1 month, 6 months, and annually thereafter. The mean (SD) follow-up duration for this cohort was 35.2 (15.6) months.

Assessments included alignment and version testing by repeating PACT in nine gazes. Success was defined as ≤10 PD horizontal and ≤8 PD vertical deviation in primary position [14]. Torsion was tested using fundus photography and double Maddox rod. For measurement reproducibility, all measurements were recorded three times and the average values were taken. Complications were assessed by surveilling for vertical deviation, torsional diplopia, suture extrusion, and infection.

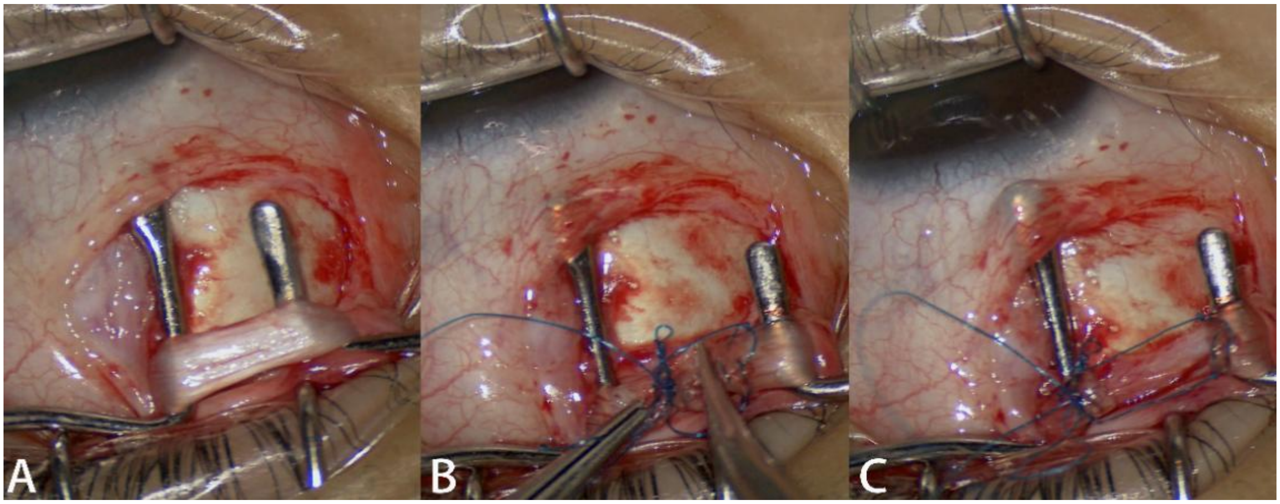

Figure 1. (A) Strabismus hook used to expose the oblique muscle tendon. (B) Suture spacer elongation procedure. (C) Tendon transected with suture spacing consistent with the surgical design.

Statistical analyses were conducted with SPSS (IBM SPSS Statistics for Windows, version 23.0, IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean (standard deviation [SD]) and range. The preoperative and postoperative strabismus correction outcomes were compared using paired *t*-test and, a *P*-value <0.05 was defined as a statistically significant difference.

RESULTS

Sixty-four eyes of pediatric patients with A-pattern esotropia and bi-SOOA (Figure 2) underwent bilateral SOSE combined with horizontal rectus recession. Of the 32 children, 18 were boys (56.3%) and 14 girls (43.7%). Mean (SD) age at time of surgery was 7.0 (3.1) years (range: 3–16). Mean (SD) postoperative follow-up was 35.2 (15.6) months (range: 8–55). All patients met inclusion criteria, with spherical equivalent of baseline refractive error and axial length ranging from -1.25 D to +2.75 D and 20.7 mm to 23.9 mm, respectively (Table 1).

Concerning primary outcomes, the mean (SD) of preoperative A-pattern magnitude (23.4 [7.7] PD) significantly collapsed postoperatively to 2.4 (2.3) PD ($P < 0.001$), representing an 88.3% reduction. Likewise, the mean (SD) of preoperative SOOA grades using a 9-point scale (2.8 [0.7]) decreased significantly at the postoperative visit (0.2 [0.4]) ($P < 0.001$), evidencing near-normalization. Concerning horizontal alignment, the mean (SD) of preoperative esodeviation in primary gaze (37.5 [10.9] PD) improved significantly to 1.7 [1.8] PD postoperatively ($P < 0.001$) (Table 2). Esodeviation in up-gaze and down-gaze similarly resolved. The mean (SD) preoperative esodeviation in up-gaze and down-gaze were 50.5 (10.4) PD and 27.0 (10.6) PD, respectively, and at the postoperative visit measured 3.1 (2.5) PD ($P < 0.001$) and 0.7 (1.3), respectively ($P < 0.001$) (Table 2).

Table 1. Baseline demographics and clinical characteristics of the study participants

Variables	Values
Participants (eyes), n	32 (64)
Sex (Boys / Girls), n (%)	18 (56.3) / 14 (43.7)
Age (y), Mean ± SD (Range)	7.0 ± 3.1 (3 to 16)
Follow-up (m), Mean ± SD (Range)	35.2 ± 15.6 (8 to 55)
Spherical equivalent (D), Mean ± SD (Range)	1.71 ± 1.73 (−1.25 to +2.75)
Axial length (mm), Mean ± SD (Range)	22.2 ± 1.2 (20.7 to 23.9)
A-pattern magnitude (PD), Mean ± SD (Range)	23.4 ± 7.7 (10 to 40)
SOOA (9-point scale), Mean ± SD (Range)	2.8 ± 0.7 (+ 1 to + 4)
Esodeviation in primary gaze (PD), Mean ± SD (Range)	37.5 ± 10.9 (20 to 60)
Esodeviation in up-gaze (PD), Mean ± SD (Range)	50.5 ± 10.4 (40 to 70)
Esodeviation in down-gaze (PD), Mean ± SD (Range)	27.0 ± 10.6 (0 to 50)
Objective fundus intorsion (degree), Mean ± SD (Range)	10.9 ± 2.5 (6 to 17)

Abbreviations: n, number; %, percentage; y, years; SD, standard deviation; m, months; D, diopters; mm, millimeters; PD, prism diopters; SOOA, superior oblique overaction. Note: A-pattern magnitude was calculated by subtracting the up-gaze measurement from the down-gaze measurement.

Table 2. Preoperative and postoperative outcome measures.

Variable	Preoperative value	Postoperative value	*P*-value
A-pattern magnitude (PD), Mean ± SD (Range)	23.4 ± 7.7 (10 to 40)	2.4 ± 2.3 (0 to 8)	**< 0.001**
SOOA (9-point scale), Mean ± SD (Range)	2.8 ± 0.7 (+ 1 to + 4)	0.2 ± 0.4 (0 to +1)	**< 0.001**
Esodeviation in primary gaze (PD), Mean ± SD (Range)	37.5 ± 10.9 (20 to 60)	1.7 ± 1.8 (0 to 5)	**< 0.001**
Esodeviation in up-gaze (PD), Mean ± SD (Range)	50.5 ± 10.4 (40 to 70)	3.1 ± 2.5 (0 to 8)	**< 0.001**
Esodeviation in down-gaze (PD), Mean ± SD (Range)	27.0 ± 10.6 (0 to 50)	0.7 ± 1.3 (-1 to 5)	**< 0.001**
Objective fundus intorsion (degree), Mean ± SD (Range)	10.9 ± 2.5 (6 to 17)	1.1± 1.4 (0 to 5)	**< 0.001**

Abbreviations: PD, prism diopters; SD, standard deviation; SOOA, superior oblique overaction. Note: *P*-values < 0.05 are shown in bold; A-pattern magnitude was calculated by subtracting the up-gaze measurement from the down-gaze measurement.

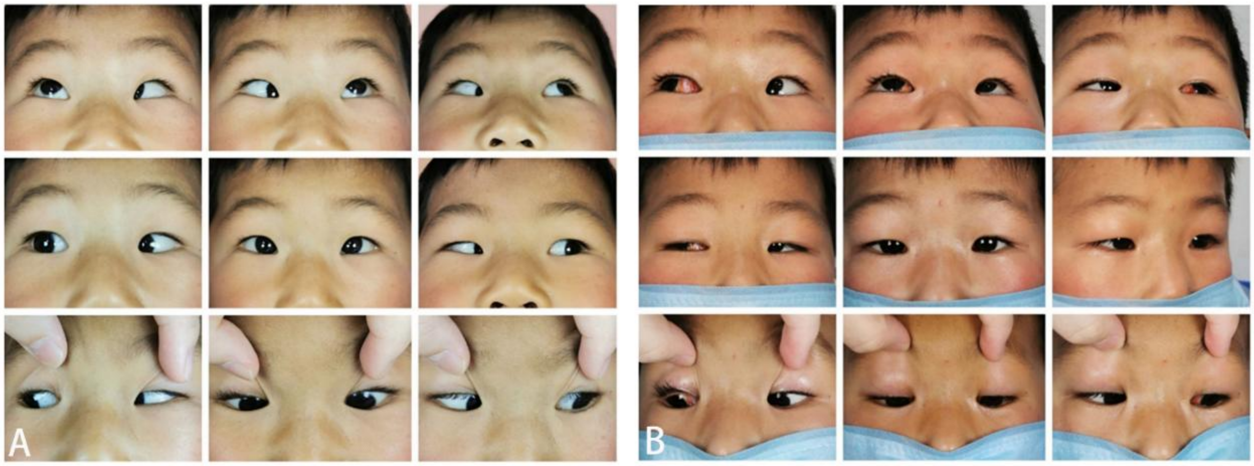

Figure 2. A 4-year-old boy admitted with bilateral esotropia since birth. Visual acuity: OD 0.6 (decimal), OS 0.6 (decimal). Prism examination: supraversion 25 degrees: +50 prism diopters (PD); primary position: +30 PD; infraversion 25 degrees: +20 PD. Bilateral superior oblique muscle overaction was noted. Nine gaze positions of an A-pattern esotropia patient treated with bilateral superior oblique tendon suture extension (SOSE) are shown. (A) Preoperative image showing over-elevation in adduction of both eyes. (B) Postoperative one day after bilateral SOSE shows orthotropic ocular alignment.

Torsional correction was assessed using the mean (SD) objective fundus intorsion, which decreased significantly from 10.9 (2.5) degrees preoperatively to 1.1 (1.4) degrees postoperatively (*P* <0.001) (Table 2). Subjective torsion via double Maddox rod testing corroborated these findings, with no patients reporting torsional diplopia.

Concerning surgical parameters, the length of the SO suture spacer ranged from 4 to 7 mm with a mean (SD) of 5.9 (0.9) mm, with most patients receiving 6-mm lengthening. Intraoperative PETT-guided adjustments ensured graded tendon lengthening without overcorrection.

Concerning safety and complications, no postoperative vertical deviation (>8 PD), torsional diplopia, or suture-related complications (e.g., extrusion, infection) were observed. All patients maintained anatomical integrity of the superior oblique insertion, confirmed via fundus photography. Long-term alignment stability persisted through follow-up, with no cases of A-pattern recurrence. Postoperative deviations at final follow-up (55 months) remained within 5 PD of immediate surgical outcomes.

DISCUSSION

This study demonstrates that bilateral SOSE combined with horizontal rectus recession is a safe and highly effective intervention for pediatric A-pattern esotropia associated with bi-SOOA. The superior oblique weakening technique was helpful to solve this situation, hence various surgical procedures have emerged to this end: partial tenotomy, tenectomy, Z-tendon lengthening, suture and silicone elongation [7–9].

Our results align with, and in several key aspects surpass, prior reports on SO-weakening techniques while addressing critical gaps in pediatric strabismus literature. The 88.3% reduction in A-pattern deviation and near-complete resolution of horizontal esodeviation (95.5% reduction in primary gaze) observed in our cohort exceed outcomes from traditional tenotomy or silicone spacer techniques. For instance, Awadein et al. [7] reported a 75–80% reduction in A-pattern deviation using silicone spacers, but with a 12% incidence of spacer extrusion and restricted ductions [7]. In contrast, our hardware-free SOSE approach achieved superior stability (no recurrences over 55 months) and eliminated implant-related complications. Xia et al. [5] described graded suture lengthening outcomes; however, their study combined pediatric and adult data and did not include long-term follow-up [5]. Our work bridges this gap, demonstrating that SOSE is uniquely suited for children, whose dynamic ocular growth [12] demands anatomically conservative techniques.

The biomechanical rationale for SOSE lies in its ability to modulate SO tension without disrupting anatomical insertion of the tendon [5]. By creating a controlled gap (4–7 mm) secured with nonabsorbable sutures, SOSE avoids the abrupt force decay associated with tenotomy, which destabilizes the tendon's pulley system. This is critical in pediatric patients, where preserving orbital anatomy ensures compatibility with ongoing ocular growth [15, 16]. Recent computational models by Wei et al. [9] emphasize that SO overaction in A-pattern esotropia arises from disproportionate tension in the posterior tendon fibers [9]. The SOSE technique, through graded lengthening, specifically targets these fibers, which explains the marked reduction in SOOA grades (2.8 to 0.2) and the absence of postoperative vertical deviations.

The postoperative reduction in SOOA grade from 2.8 to 0.2, along with torsional correction from 10.9 to 1.1 degrees, further supports SOSE precision. These outcomes outperform those of tenotomy (which risks unpredictable torsional instability) and recession [17] (which may undercorrect due to scleral insertion variability). Preservation of the native insertion of the SO tendon in SOSE likely preserves physiological tension gradients, minimizing iatrogenic torsion—a critical advantage underscored by the absence of torsional diplopia in our cohort. To avoid silicone-sclera adhesions [7, 18] and orbital fat adherence syndrome [19, 20], keeping the intermuscular septum intact and maintaining Tenon capsule integrity are crucial in operation. To minimize foreign material scar adhesions and avoid extrusion, researchers suggested using non-absorbable sutures, which allow for adjustment intraoperatively and postoperatively and is technically easier as well as time-saving [3, 10]. In our series, no such complications were observed in nearly three years of follow-up.

The strengths and innovations of this approach include its hardware-free safety, as it avoids the use of silicone implants, thereby eliminating risks of extrusion, inflammation, and fibrosis, complications noted in silicone spacer cases [18, 21, 22], and aligns with the increasing preference for suture-only techniques in pediatric surgery. Additionally, the method allows for combined correction of A-pattern and esotropia through simultaneous horizontal rectus recession and SOSE [5, 7, 8], which simplifies surgical planning and reduces operative time by avoiding vertical transposition. The former results indicated that, even performed in the same operation, the surgical outcome of the A-pattern and the horizontal correction had no interference with each other [23, 24]. We found similar results that both the horizontal and vertical strabismus were significantly improved in our study.

The procedure demonstrates long-term stability, supported by a mean follow-up of 35 months and extending up to 55 months, providing strong evidence of durability, an essential factor for pediatric patients who require sustained binocularity. Our study suggests that intorsions were corrected, which is comparable with previous spacer surgery by the same graded method [14]. Moreover, the use of fundus photography for torsion measurement [5, 8] enhances the objectivity and reliability of torsion assessment, offering a more rigorous approach compared to the subjective methods used in previous studies.

Our findings position SOSE as a first-line intervention for pediatric bi-SOOA. The procedure's adjustability, preserved anatomy, and compatibility with concurrent horizontal surgery make it particularly advantageous for complex strabismus cases. Furthermore, the absence of vertical deviation or reoperations underscores its safety profile, critical in children with developing visual systems. While our study provides compelling evidence, limitations include its retrospective design and small sample size. The absence of stereopsis assessment (e.g., Titmus test) may limit interpretation of functional visual outcomes. Future prospective, multicenter studies with larger cohorts should incorporate these metrics and stratify outcomes by age or suture length. Comparative trials against silicone spacers or tenotomy could further validate SOSE's superiority.

CONCLUSIONS

This study demonstrates that SOSE presents a viable surgical alternative for pediatric A-pattern esotropia with bi-SOOA, combining anatomical preservation, procedural simplicity, and favorable postoperative outcomes. The technique avoids implant dependence and reduces surgical invasiveness while effectively addressing both horizontal and torsional deviations. These findings suggest that SOSE may enhance safety and efficacy in managing strabismus in pediatric patients. The implications of this study support the adoption of SOSE as a valuable option in clinical practice, particularly for cases requiring a hardware-free approach. However, future randomized trials with larger cohorts and longer follow-up periods are needed to establish the efficacy and safety of this procedure in managing A-pattern esotropia. Future investigations should focus on validating these results through larger, comparative studies and exploring functional outcomes, long-term stability, and potential adaptations to other strabismus subtypes, such as exotropia or adult cases.

ETHICAL DECLARATIONS

Ethical approval: This project was approved by the Institutional Ethical Review Board of Shanghai Children's Hospital, following the ethical standards of the Helsinki declaration and the corresponding amendments (Approval No: 2023R090-E01). Informed consent was obtained from all the parents or legal guardians of the individual participants included in the study. The participants were fully informed about the nature, purpose, and potential implications of publication of their identifying information/images in this online open-access publication and provided informed consent for publication.

Conflict of interest: None.

FUNDING

This study was supported by grants from Shanghai Children's Hospital Clinical Research Fund Project (No. 2021YLYM08).

ACKNOWLEDGMENTS

None.

REFERENCES

1. Kushner BJ. Torsion and pattern strabismus: potential conflicts in treatment. JAMA Ophthalmol. 2013 Feb;131(2):190-3. doi: 10.1001/2013.jamaophthalmol.199. PMID: 23411884.
2. Kekunnaya R, Mendonca T, Sachdeva V. Pattern strabismus and torsion needs special surgical attention. Eye (Lond). 2015 Feb;29(2):184-90. doi: 10.1038/eye.2014.270. Epub 2014 Nov 21. PMID: 25412718; PMCID: PMC4330283.
3. Goldenberg-Cohen N, Tarczy-Hornoch K, Klink DF, Guyton DL. Postoperative adjustable surgery of the superior oblique tendon. Strabismus. 2005 Mar;13(1):5-10. doi: 10.1080/09273970590889941. PMID: 15824010.
4. Debert I, Darcie ALF, Polati M. Bilateral superior oblique temporal tenectomy for the treatment of A-pattern strabismus. J AAPOS. 2020 Aug;24(4):222.e1-222.e4. doi: 10.1016/j.jaapos.2020.04.012. Epub 2020 Aug 27. PMID: 32861855.
5. Xia W, Wu L, Yao J, Wen W, Wang X, Jiang C, Li L, Zhao C. Graded superior oblique tendon suture lengthening: A novel procedure. Eur J Ophthalmol. 2021 Sep;31(5):2639-2646. doi: 10.1177/1120672120968726. Epub 2020 Nov 11. PMID: 33176500.
6. Sanjari MS, Shahraki K, Nekoozadeh S, Tabatabaee SM, Shahraki K, Aghdam KA. Surgical treatments in inferior oblique muscle overaction. J Ophthalmic Vis Res. 2014 Jul-Sep;9(3):291-5. doi: 10.4103/2008-322X.143355. PMID: 25667727; PMCID: PMC4307652.
7. Awadein A, Gawdat G. Comparison of superior oblique suture spacers and superior oblique silicone band expanders. J AAPOS. 2012 Apr;16(2):131-5. doi: 10.1016/j.jaapos.2011.11.011. PMID: 22525167.
8. Yu J, Cen J, Zhao P, Kang X. Evaluation of three superior oblique surgical weakening procedures for A-pattern strabismus. Arq Bras Oftalmol. 2019 Jun 27;82(5):417-421. doi: 10.5935/0004-2749.20190079. PMID: 31271573.
9. Wei Q, Mutawak B, Demer JL. Biomechanical modeling of actively controlled rectus extraocular muscle pulleys. Sci Rep. 2022 Apr 6;12(1):5806. doi: 10.1038/s41598-022-09220-x. PMID: 35388039; PMCID: PMC8987043.
10. Suh DW, Guyton DL, Hunter DG. An adjustable superior oblique tendon spacer with the use of nonabsorbable suture. J AAPOS. 2001 Jun;5(3):164-71. doi: 10.1067/mpa.2001.114190. PMID: 11404743.
11. Nihalani BR, Hunter DG. Adjustable suture strabismus surgery. Eye (Lond). 2011 Oct;25(10):1262-76. doi: 10.1038/eye.2011.167. Epub 2011 Jul 15. PMID: 21760626; PMCID: PMC3194320.
12. Zhang Z, Mu J, Yang Y, Dai Y, Duan J. Influence of dynamic changes of ocular biometric parameters on new-onset myopia in Chinese children: a 4-year cohort study. Sci Rep. 2025 Aug 4;15(1):28474. doi: 10.1038/s41598-025-14453-7. PMID: 40760005; PMCID: PMC12322155.
13. Hernández García E, Gómez de Liaño Sánchez MR. Correlation study in the measurements of oblique passive ductions and cyclorotation. Arch Soc Esp Oftalmol (Engl Ed). 2020 Aug;95(8):373-378. English, Spanish. doi: 10.1016/j.oftal.2020.04.008. Epub 2020 Jun 16. PMID: 32553797.
14. Jethani J, Shah K, Amin S. Effect of bilateral superior oblique split lengthening on torsion. Indian J Ophthalmol. 2015 Mar;63(3):250-3. doi: 10.4103/0301-4738.156929. PMID: 25971171; PMCID: PMC4448239.
15. Bhat R, Al-Samarraie M, Nada A, Leiva-Salinas C, Whitehead M, Mahdi E. Spotlight on the pediatric eye: a pictorial review of orbital anatomy and congenital orbital pathologies. Neuroradiol J. 2021 Feb;34(1):21-32. doi: 10.1177/1971400920949232. Epub 2020 Aug 31. PMID: 32865127; PMCID: PMC7868591.
16. Tran AQ, Kazim M. Orbital Surgical Guidelines: Pediatric Considerations. J Neurol Surg B Skull Base. 2021 Feb;82(1):142-148. doi: 10.1055/s-0040-1722637. Epub 2021 Mar 1. PMID: 33777627; PMCID: PMC7987405.
17. Roizen A, Velez FG, Rosenbaum AL. Superior oblique anterior tenectomy. J AAPOS. 2008 Feb;12(1):54-7. doi: 10.1016/j.jaapos.2007.07.010. Epub 2007 Oct 25. PMID: 17964208.
18. Wright KW. Results of the superior oblique tendon elongation procedure for severe Brown's syndrome. Trans Am Ophthalmol Soc. 2000;98:41-8; discussion 48-50. PMID: 11190035; PMCID: PMC1298210.
19. Özkan SB. Restrictive problems related to strabismus surgery. Taiwan J Ophthalmol. 2016 Jul-Sep;6(3):102-107. doi: 10.1016/j.tjo.2016.05.001. Epub 2016 Jun 20. PMID: 29018723; PMCID: PMC5525619.

20. Olitsky SE, Coats DK. Complications of Strabismus Surgery. Middle East Afr J Ophthalmol. 2015 Jul-Sep;22(3):271-8. doi: 10.4103/0974-9233.159692. PMID: 26180463; PMCID: PMC4502168.
21. Fu L, Gurnani B, Malik J. Brown Syndrome. 2024 Mar 3. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2025 Jan–. PMID: 33085357.
22. Ugurbas SC, Kocer NE, Oto S, Kahraman B, Akova YA. Comparison of alloplast materials in experimental extraocular muscle surgery. Ophthalmic Res. 2010;44(1):50-6. doi: 10.1159/000292260. Epub 2010 Mar 8. PMID: 20215807.
23. Ron Y, Snir M, Axer-Seigel R, Friling R. Z-tenotomy of the superior oblique tendon and horizontal rectus muscle surgery for A-pattern horizontal strabismus. J AAPOS. 2009 Feb;13(1):27-30. doi: 10.1016/j.jaapos.2008.09.004. Epub 2008 Dec 12. PMID: 19084442.
24. Yassin SH, Tsai J, Mossadeghian T, Kefalov Y, Lam S, Shahraki K, Amin M, Suh DW. Introducing the Novel Muscle Hook for Challenging Strabismus Surgery. J Binocul Vis Ocul Motil. 2025 Jan-Mar;75(1):6-10. doi: 10.1080/2576117X.2025.2488575. Epub 2025 Apr 11. PMID: 40211800.