SURGICAL TECHNIQUES

Comparison of a new, minimally invasive strabismus surgery technique with the usual limbal approach for rectus muscle recession and plication

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Aim: To present a novel, minimally invasive strabismus surgery (MISS) technique for rectus muscle operations.

Methods: In this prospective study with a non-concurrent, retrospective comparison group, the first 20 consecutive patients treated with MISS were matched by age, diagnosis and muscles operated on, with 20 patients with a limbal opening operated on by the same surgeon at Kantonsspital, St Gallen, Switzerland. A total of 39 muscles were operated on. MISS is performed by applying two small radial cuts along the superior and inferior muscle margin. After muscle separation from surrounding tissue, a recession or plication is performed through the resulting tunnel. Alignment, binocular single vision, variations in vision, refraction, and number and types of complications during the first 6 postoperative months were registered.

Results: Visual acuity decreased at postoperative day 1 in both groups. The decrease was less pronounced in the group operated on with MISS (difference of decrease 0.14 logMAR, $p < 0.001$). An abnormal lid swelling at day 1 was more frequent in the control group (21%, 95% confidence interval (CI) 9% to 41%, 5/24 v 0%, 95% CI 0 to 13%, 0/25, $p < 0.05$). No significant difference was found for final alignment, binocular single vision, other visual acuities, refractive changes or complications (allergic reactions, dellen formation, abnormal conjunctival findings). A conversion to a limbal opening was necessary in 5% (95% CI 2% to 17%, 2/39) of muscles.

Conclusions: This study shows that this new, small-incision, minimal dissection technique is feasible. The MISS technique seems to be superior in the direct postoperative period as better visual acuities and less lid swelling were observed. Long-term results did not differ in the two groups.

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Minimally invasive surgery has been one of the most important revolutions in surgical techniques since the early 1900s.^{1,2} In many operating disciplines, it allows minimisation of tissue traumatism, postoperative patient discomfort, hospital stay and working disability. Minimal surgical techniques are now routine—for example, for cholecystectomy, splenectomy, adrenalectomy and sentinel node biopsy.¹

In ophthalmology, many minimally invasive procedures have been developed over the past decades—for example, for phacoemulsification for cataracts,³ non-penetrating techniques⁴ and miniature drainage implants for glaucoma,⁵ transconjunctival approaches⁶ and minimal buckling for vitreoretinal surgery,⁷ endoscopic techniques for the lacrimal system,⁸ and small-incisions for lids.⁹ In strabismus surgery, some attempts have been made to reduce the conjunctival incision size as it is one of the major components contributing greatly to postoperative quality of life, cosmesis and later the function of the operated muscle. The type of conjunctival opening also influences the ease to perform revision surgery. Many surgeons use the limbal approach first described by Harms in 1949¹⁰ and later popularised by von Noorden,^{11,12} allowing direct access to Tenon's space for horizontal muscle recession, resection or plication. The conjunctiva is raised as a flap at the limbus with two radial incisions along both muscle borders¹¹ (fig 1A). The opening can be started either perilibally¹¹ or radially to the limbus.¹³ One modification of this technique is to perform only one radial incision (fig 1B). Several other access techniques have been described for horizontal rectus muscle surgery. Swan suggested a conjunctival incision parallel to the limbus close to the fornix, followed by a radial incision of Tenon's capsule over the bulk of the muscle (fig 1C).¹⁴ After muscle surgery, Tenon's

capsule and conjunctiva have to be closed separately. Parks advocated a fornix incision for conjunctiva and Tenon's capsule.¹⁵ Unless the muscle has to be supraplaced, the lower fornix is selected (fig 1D). In younger patients with elastic conjunctiva it enables the opening to be made over the muscle, allowing full visualisation of the surgical procedure. This technique is widely used in the USA. Velez suggested a radial incision covered by the upper lid. For medial rectus surgery the incision is made in the nasal superior quadrant, and for lateral rectus surgery in the temporal superior quadrant¹⁶ (fig 1E). Santiago tried a paralimbal approach with an opening placed halfway between the limbus and the muscle insertion¹⁷ (fig 1F).

In this study, a new access for horizontal rectus muscle recession and plication has been used. Muscle exposure was performed through only two small radial cuts, one along the superior and the other along the inferior margin of the horizontal muscles, allowing to perform minimally invasive strabismus surgery (MISS), as the opening and tissue dissection are minimised. Postoperatively, such openings will remain covered by the lids apart from during upgaze and excessive lateral gaze.

PATIENTS

This study presents the results of the first 20 consecutive patients operated on with the MISS technique at Kantonsspital, St Gallen, Switzerland. The investigation followed the tenets of the Declaration of Helsinki. The president of the Ethical Committee of Kanton, St Gallen, has approved the use of this new technique.

Abbreviation: MISS, minimally invasive strabismus surgery

Figure 1 Schematic representation of the most important types of conjunctival openings reported in the literature. The eye is represented as seen by the surgeon (upper eyelid is inferior). (A) Classical limbal approach with two radial cuts. (B) Variation of (A), with only one radial cut. (C) Conjunctival incision parallel to the limbus close to the fornix. (D) Lower fornix incision. (E) Radial incision covered by the upper lid. (F) Paralimbal approach with an opening placed halfway between the limbus and the muscle insertion.

Patients undergoing MISS

Inclusion criteria: During a 5-month period, the first 21 consecutive patients needing horizontal rectus muscle surgery operated on by the author were prospectively included. **Exclusion criteria:** Patients with one or more of the following were operated with the usual, limbal approach: excessive conjunctival scarring from previous surgery, previous muscle recession, need for retroequatorial fixation sutures, vertical rectus muscle surgery, muscle transposition, recessions >7 mm, plications >9 mm or expectation of increased bleeding level (eg, diagnosis of endocrine orbitopathy or acetyl-salicylic acid intake). One patient with an intracranial tumour was lost from follow-up and was therefore excluded. All patients had at least one complete orthoptic examination 5 days before the surgical procedure, on the first postoperative day and after 6 months (range 5–7 months) at the Department of Strabismology and Neuro-Ophthalmology. Between day 1 and month 6, only patients harboring a complication or not referred by an ophthalmologist were seen at our department. The other patients were followed by the referring ophthalmologists. The schedule of follow-up visits in between was at day 10 (range 1–2 weeks) and at week 4 (range 3–5 weeks). The patients' age ranged from 3.3 to 74.3 years (mean (standard deviation (SD)) 27.1 (20.9) years).

Patients with traditional, limbal approach

Patients with MISS were matched by age at the time of surgery (± 4 years), by diagnosis and by muscles operated on, with a group of patients operated on by with the limbal approach (fig 1A) in the 34th month before starting the MISS technique.

Matching was performed in a masked manner without knowledge of surgical outcome. Two patients could not be matched for all three criteria. One 51-year-old patient with large exotropia with bilateral lateral rectus recession and unilateral medial rectus plication was matched with another 26-year-old patient with the same diagnosis and same operated muscles. One 3-year-old patient with a large congenital esotropia with bilateral medial rectus recession and unilateral lateral rectus plication was matched for diagnosis and age. However, only one patient with unilateral medial rectus recession and lateral rectus plication could be found. This is the reason for the different amount of eyes in the two groups. In the control group, ages ranged from 4.6 to 75.4 years (mean (SD) 24.4 (20.5) years). Follow-up was identical to that described for the MISS group. All study patients were re-examined at our department 6 months later.

Outcome measures

Final alignment, binocular single vision, variations in vision, refraction, and number and types of complications and retreatments required during the first 6 months after surgery were the outcome measures.

METHODS

Surgical technique for MISS

The whole surgical procedure is performed under the operating microscope under general anaesthesia. All surgical steps can be performed by oneself, so there is no need for an assistant. First, a limbal traction suture (Silkam 6-0 or Safil 6-0, B Braun Medical, Seesatz, Switzerland) is applied to rotate the eyeball

Figure 2 Schematic representation of the new minimally invasive strabismus surgery technique. The eye is represented as seen by the surgeon (upper eyelid is inferior). (A) Two small cuts are placed at the upper and lower borders of the muscle insertion. (B) The muscle insertion is dissected from surrounding tissue. (C) The tendon is hooked. (D–F) Muscle recession. (D) Two sutures are placed through the upper and lower parts of the muscle insertion. (E) The muscle is disinserted. (F) The muscle is reattached after recession. (G–I) Muscle plication. (G) Two sutures are placed at the upper and lower borders of the muscle at the distance from the tendon insertion site corresponding to the plication amount. (H) Application of the iris spatula. (I) Plication. (J) Closure of both openings. (K, L) Procedures if larger openings become necessary. (K) Anterior prolongation of both cuts. (L) Anterior prolongation and joining by a limbal cut.

Figure 3 Photographs showing four steps of a muscle plication in one of the patients operated on with minimally invasive strabismus surgery reported in this study. The eye is shown as seen by the surgeon (upper eyelid is inferior). (A) A suture is placed at the upper border of the lateral rectus muscle at 4.5 mm from the tendon insertion site. (B) Plication of the muscle. (C) Appearance of the eye after closing of the cuts for a slight right-upgaze position. (D) Appearance of the eye in primary position after closing of the cuts.

away from the field of surgery (fig 2A). During surgery, a direct contact of the traction suture with the cornea has to be avoided. Then, two small radial cuts are performed, one along the superior and the other along the inferior muscle margin (fig 2A). The anterior margin of the cut is at the level of the tendon insertion. The size of the cuts will depend on the amount of muscle displacement that has to be achieved. As a rule of the thumb, the opening size will be 1 mm less than the amount of muscle displacement which has to be achieved. For example, a recession or plication of 4 mm can be performed through two 3-mm openings. Usually, for sizes >5 mm, an opening of 2 mm less than the amount is sufficient. In patients with reduced elasticity of the conjunctival tissue, slightly larger openings will be necessary. With blunt Wescott scissors using the two cuts for access, the episcleral tissue is separated from the muscle sheath and the sclera (fig 2B). When the borders of the muscles have been identified, the muscle is hooked. Then, a meticulous dissection of the check ligaments and intramuscular membrane is performed (fig 2C). This dissection is performed 6–7 mm backward to the insertion. The resulting tunnel allows a recession or plication to be easily performed. We performed plications however, the tunnel also allows resections. To perform a recession, two sutures (Vicryl 7-0, Ethicon, Spreintebach, Switzerland) are applied to the superior and inferior borders of the muscle tendon as close as possible to the insertion (fig 1D). Then, the tendon is detached using a Wescott scissor (fig 1E). If necessary, haemostasis is performed. After measurement of the amount of recession, the tendon is reattached with the two sutures to the sclera (fig 2F). The tendon has to be stretched to avoid the middle part of the muscle bowing backwards. To perform a plication, two sutures

(Vicryl 7-0, Ethicon, Switzerland) are applied to the upper and lower borders of the muscle at the distance from the tendon insertion site corresponding to the plication amount (fig 2G). Then, the sutures are passed at the superior and inferior tendon insertions. An iris spatula is inserted between the tendon and the sutures (fig 2H) and the muscle is plicated (fig 2I). The surgical procedure is finished by applying two sutures (Vicryl Rapid 8-0, Ethicon) to each of the two small cuts (fig 2J). At the end of surgery, Tobradex ointment (1 mg dexamethasone and 3 mg tobramycin per gram of 0.5% chlorobutanol) was applied. No eye patch was used. For the first 2 weeks after surgery, the following treatment was prescribed: Tobradex suspension (1 mg dexamethasone and 3 mg tobramycin per ml of 0.01% benzalkonium chloride) thrice daily and Tobradex ointment in the evening. Figure 3 shows a 4.5 mm lateral rectus plication in the left eye of a 74-year-old patient. After the two small cuts have been applied, a suture is applied 4.5-mm behind the muscle insertion (fig 3A). The muscle is plicated using an iris spatulum (fig 3B). After closing the cuts, only a minimal redness of the conjunctiva is visible (fig 4A in the slightly right-upgaze, fig 4B in the primary position). At any time during surgery the cuts can be prolonged anteriorly (fig 2K), and, if necessary, joined with a limbal cut (fig 2L). This can become necessary if excessive bleeding occurs, which cannot be stopped with cautery through the small cuts or in patients with previous surgery with excessive scarring.

Surgical technique for traditional, limbal approach

The whole surgical procedure is performed under the operating microscope under general anaesthesia. First, a limbal silk traction suture (Silkam 6-0 or Safil 6-0, B Braun Medical) is

Figure 4 (A) Photograph at 24 hours and (B) at 2 weeks after surgery of the patient described in figure 3, with bilateral lateral rectus plication of 4.5 mm. Informed patient consent was obtained.

applied to rotate the eyeball away from the field of surgery. Then, a limbal opening with two radial relaxing incisions of 3 mm is performed (fig 1A). With blunt Wescott scissors the episcleral tissue is separated from the muscle sheath and the sclera. When the borders of the muscles have been identified, the muscle is hooked. Then, a meticulous dissection of the check ligaments and intramuscular membrane is performed. Then, a recession or plication is performed in the same manner as described for the MISS technique. The surgical procedure is finished by readapting the conjunctiva, applying four to six sutures (Vicryl Rapid 8-0, Ethicon, Switzerland). At the end of surgery, Tobradex ointment was applied. No eye patch was used. For the first 2 weeks after surgery, application of Tobradex suspension three times daily and Tobradex ointment in the evening was prescribed.

Statistical methods

Fisher's exact test was used for the comparison of the following variables between MISS and standard technique: sex, muscles with previous surgery, binocular vision, refractive changes, final alignment, number of allergic reactions, dellen formation and conjunctival abnormalities. The χ^2 test was used to compare the total number of eyes with abnormalities at the first post-operative day. The paired t test was used to compare the age between groups and for differences of logMAR visual acuities within the groups, the unpaired for comparisons of logMAR visual acuities between MISS and the standard technique. The power to detect differences between two proportions depends on the expected proportion. For most comparisons of proportions performed in that study (>90%), critical differences of <0.2 would have been detected with a power of 0.8 and a confidence of 0.9. Two non-significant comparisons in this study allow detecting critical differences of only approximately 0.3. The two inconvenient values are found for the parameters binocular vision at month 6 and alignment at month 6. As muscle surgery is performed identically in those operated on with MISS and in controls, large differences in these two

parameters are unlikely. The power to detect differences between two non-significant, normally distributed variables was calculated using the pooled variance. Assuming a two-sided test, a power of 0.8 and a confidence of 0.9, differences of <0.1 would have been detected for all comparisons performed.

RESULTS

Table 1 shows the preoperative characteristics of patients operated on with MISS and controls.

No statistical difference was found between the groups for sex, age and number of muscles previously operated on. In two of 39 (5%) muscles, conversion from a minimal opening to a normal conjunctival opening was necessary to stop bleeding. In both cases there was a cause for excessive bleeding. In one, muscle scarring from previous surgery was unexpectedly extensive. The other patient had a previously unknown intake of acetyl-salicylic acid. Both patients did not develop complications during follow-up. Table 2 summarises types of strabismus of the patients operated on with the MISS techniques and the controls.

Frequencies are identical for patients operated on with MISS and controls as patients were matched for diagnosis. Table 3 shows the postoperative results of both groups.

The amount of surgery was similar in both groups. Visual acuities decreased in both groups at day 1 after surgery. The decrease was much less pronounced in the MISS group (difference of decrease between groups 0.14 logMAR, $p < 0.001$). All other visual acuity comparisons (day 1 and month 6) did not show significant differences. At month 6, binocular vision was also similar in both groups, with an increase for both groups after surgery. Only slight and similar refractive changes were observed after month 6 in both groups (for all eyes ≤ 0.5 dioptres (dpt) of spherical equivalent respective astigmatism change). Proportions of successful final alignment at month 6 were similar in both groups for both criteria used. 65% (13/20) of patients operated on with MISS and 60% (12/20) of controls had an alignment ≤ 10 prism

Table 1 Preoperative characteristics of patients operated on with MISS and controls

	MISS, 20 patients	Controls, 20 patients	p Value
Eyes	25	24	–
Recessed muscles	21	20	–
Plicated muscles	18	18	–
Sex	11/20 (55%)	10/20 (50%)	>0.1
Age (years)	27.1 (20.9)	24.4 (20.5)	>0.05*
Previously operated muscles	2/39 (5%)	2/39 (5%)	>0.1

MISS, minimally invasive strabismus surgery.

*The age of the patient with age match >4 years is included.

Table 2 Frequencies of types of strabismus. Since the type of strabismus was one of the matching criteria, frequencies are identical for patients operated on with MISS (n = 20) and controls

	Frequencies (%)
Esodeviations:	
Essential infantile esotropia	4/20 (20)
Esotropic microstrabismus	5/20 (25)
Esotropic myopic myopathy	2/20 (10)
Esotropia with normal retinal correspondence	3/20 (15)
Exodeviations:	
Primary exotropias	4/20 (20)
Exotropic microstrabismus	1/20 (5)
Essential infantile esotropia*	1/20 (5)

(n = 20).

*At time of surgery consecutive exotropia

diopters (pdpt) for near or distance. 90% (18/20) of patients operated on with MISS and 85% (17/20) of controls had an alignment ≤ 10 pdpt for near and distance. Apart from more abnormal lid swellings in the control group (21%, 5/24 v 0%, 0/25, $p < 0.05$), no significant differences were found at postoperative day 1. In both groups the same number of allergic reactions from topical eye drops have been observed. They all resolved after discontinuing the use of eye drops. One patient in each group had a dellen formation, which resolved under lubrication. Although at postoperative month 6 an increase in conjunctival redness could be observed in 8% (2/24) of control eyes and in none of the patients operated on with MISS, the difference was not significant. Figure 4 shows the postoperative appearance after 24 h and 2 weeks in a 74-year-old patient with bilateral lateral rectus plication.

DISCUSSION

Minimally invasive surgery is becoming important in almost every facet of surgery, including eye surgery. Instrument miniaturisation, endoillumination and optical improvements have changed and will continue to influence the way in which surgery is performed. In this study, the results of 39 horizontal rectus muscles operated on with a novel MISS technique in 20 patients have been presented. Squint surgery is performed through two small radial cuts along the superior and inferior muscle margin (fig 2). Postoperatively, these openings remain covered by the lids apart from during upgaze and excessive lateral gaze, which minimises visibility of the surgical procedure during the immediate postoperative period. If a better visibility of the operative site is needed, this type of cut can be prolonged anteriorly (fig 2K) or even joined with a limbal cut (fig 2L). In this patient series, this was necessary for two operated muscles. Conversion was not associated with an adverse postoperative course. The whole surgical procedure can be performed with the same instruments used for standard, limbal approach. There is no need for an assistant. Despite a restricted conjunctival opening, the MISS technique allowed adequate muscle exposure to perform displacements, minimising anatomical disruption. As a rule of the thumb, the opening size necessary to perform a recession or plication will be 1–2 mm less than the amount of muscle displacement. The exact operating time has not been monitored. The time necessary to perform an MISS recession or plication, taken from the time of anaesthesia, was approximately the same as for the usual, limbal approach. With more expertise, MISS procedures might also shorten the operating time. At 2 weeks after surgery, the eyes often looked normal or nearly normal in primary gaze position (fig 4).

A conjunctival opening situated at a reasonable distance from the cornea should decrease the incidence of corneal dellen

Table 3 Postoperative characteristics of patients operated on with MISS and controls

	20 MISS patients/25 eyes	20 controls/24 eyes	p Value
Amount of surgery			
Recession	5.2 (1.2) mm	5.8 (0.5) mm	>0.05
Plication	6.5 (1.8) mm	6.7 (2.7) mm	>0.1
Logmar visual acuity			
Preoperative	0.17 (0.24)	0.06 (0.10)	>0.1
Postoperative at day 1	0.23 (0.33)	0.26 (0.15)	>0.1
Difference between preoperative and day 1	-0.06 (0.06)	-0.20 (0.13)	<0.001
Postoperative at month 6	0.16 (0.30)	0.05 (0.07)	>0.1
Difference between preoperative and month 6	0.06 (0.01)*	0.07 (0.01)*	>0.1
Binocular vision at month 6†			
Worsening	0/20 (0, 0 to 16)	0/20 (0, 0 to 16)	>0.1
Same	14/20 (70, 48 to 85)	13/20 (65, 43 to 82)	>0.1
Improvement	6/20 (30, 15 to 52)	7/20 (35, 18 to 57)	>0.1
Refractive changes at month 6	5/25 (20, 9 to 39)‡	4/24 (17, 7 to 36)‡	>0.1
Alignment at month 6†			
Near and distance ≤ 10 pdpt	13/20 (65, 43 to 82)	12/20 (60, 38 to 78)	>0.1
Near or distance ≤ 10 pdpt	18/20 (90, 70 to 97)	17/20 (85, 64 to 95)	>0.1
Abnormal findings at day 1			
Allergic reaction to topical treatment	4/25 (16, 7 to 35)	4/24 (17, 7 to 36)	>0.1
Dellen formation	1/25 (4, 0 to 20)	1/24 (4, 0 to 20)	>0.1
Abnormal conjunctival swelling	2/25 (8, 2 to 25)	4/24 (17, 7 to 36)	>0.1
Abnormal lid swelling	0/25 (0, 0 to 13)	5/24 (21, 9 to 41)	<0.05
Abnormal findings at month 6			
Increase in conjunctival redness	0/25 (0, 0 to 13)	2/24 (8, 3 to 26)§	>0.1

MISS, minimally invasive strabismus surgery.

*Increase due to occlusion therapy in amblyopic eyes.

†Values in parentheses are percentages and 95% CI.

‡All ≤ 0.5 dpt of spherical equivalent respective astigmatism.

§Only slight increase.

formation, avoid a prolapse of Tenon's capsule and minimise postoperative discomfort. There is also increasing evidence that non-limbal strabismus surgery affects less perilimbal blood supply and may safeguard anterior segment ischaemia in high-risk patients. However, because of the low incidence of such complications, only larger studies with more statistical power will be able to show whether such complications will be less frequent with the new technique. MISS seems to be superior in the immediate postoperative period as, compared with controls, the visual acuity decrease on day 1 was much less pronounced and no abnormal lid swellings could be seen. Although not objectively measured, we had the impression that in the immediate postoperative period patient discomfort was reduced. After month 6, no significant difference was found between MISS and the control group for final alignment, binocular single vision, other visual acuities, refractive changes, number of allergic reactions and dellen formation. No increased conjunctival redness could be seen in patients operated on with MISS, whereas two patients in the control group had an increase. However, this difference was not significant and the increase of redness was only slight. Only a minimal cicatrization was found along the incision lines, which did not hinder free movement of the conjunctiva over the sclera and muscle. Sometimes even biomicroscopically it was not possible to see the scars. It could be hypothesised that this minimal scarring might facilitate reoperations.

In this study, MISS has not been compared with Parks fornix opening.¹⁵ Both techniques avoid corneal complications. The advantage of Parks technique is the better visualisation of the surgical site, whereas MISS can be performed without an assistant and in older patients with inelastic conjunctiva.

Although these first results are promising, definitive superiority of MISS over the traditional, limbal approach has to be proved by reports including larger number of patients as increased incidences of rare complications could have been missed in this study—for example, the frequency of endophthalmitis.¹⁸

In summary, the results of a new access technique for horizontal rectus muscle surgery has been presented, which seems to be safe and more rational than previous openings. Incision placement in the region where the surgical procedure of the muscle occurs allows to minimise the total opening size,

to reduce postoperative discomfort and possibly also to reduce hospital stay, working disability and complications related to limbal approaches.

Competing interests: None.

This research followed the tenets of the Declaration of Helsinki. The Ethical Committee of Kanton, St Gallen, has approved the use of this new technique.

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