Original Article

Plication or resection combined with antagonist recession in horizontal strabismus

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ABSTRACT

Background: Strengthening of extraocular muscles is a conventional procedure in the management of strabismus. Plication may be an alternative strengthening technique, and is less invasive than resection. This study compared plication and resection, each combined with antagonist muscle recession, in terms of success rates and changes in ocular deviation in the management of horizontal strabismus.

Methods: This retrospective study recruited individuals with horizontal strabismus who underwent plication (group I) or resection (group II) coupled with antagonist muscle recession. All participants underwent a detailed baseline eye and ocular motility evaluation. Demographic and clinical data were collected, including age, sex, type of preoperative strabismus (exotropia or esotropia), baseline visual acuity, mean follow-up duration, laterality of operated eye, surgical doses of correction (resection, plication, or recession) in millimeters, preoperative strabismus magnitude in prism diopters (PD), and postoperative strabismus magnitude in PD. Successful postoperative deviation was defined as ≤10 PD. At final follow-up, the success rates and degrees of change in angle of deviation were recorded.

Results: Forty-four patients were enrolled: 19 patients in group I (plication) and 25 patients in group II (resection). The groups had comparable ages, sex ratios, types of strabismus, and preoperative and postoperative angles of deviation (all $P > 0.05$). Despite comparable success rates between groups (73.7% in group I versus 64.0% in group II, $P > 0.05$), the difference (9.7%) was marginally close to the predefined clinically meaningful difference of 10%. In the esotropia subgroup, despite comparable alignment between the plication and resection groups ($P > 0.05$), the difference was clinically meaningful (17.3%), and both groups had higher success rates in the esotropia subtype than in the exotropia subtype. The rate of over- or undercorrection was not statistically or clinically different in the total and in each subtype of strabismus (all $P > 0.05$). Success rates for unilateral and bilateral cases were similar between groups (both $P > 0.05$). Changes in angle of deviation were similar for individuals with esotropia and exotropia between groups (both $P > 0.05$).

Conclusions: In esotropic and exotropic strabismus, plication and resection procedures combined with antagonist recession were similarly effective. However, further randomized, large-scale, longitudinal studies with clinical and subjective evaluations could provide practical evidence on the suitability of the plication procedure in managing various types of strabismus.

KEYWORDS

comitant strabismus, squint, esotropias, primary exotropia, exodeviation, plication, resection, recession, amblyopias

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INTRODUCTION

Strabismus is defined as misalignment of the visual axis. This condition affects 2–3% of the general population and may lead to binocular vision loss [1]. Timely management of strabismus could prevent amblyopia in childhood and optimize visual rehabilitation in affected adults [2, 3]. Strengthening of extraocular muscles is a common surgical modality in managing strabismus. Plication is considered an alternative strengthening method with the advantage of less invasiveness than resection [4]. Iris angiography has demonstrated that plication spares the ciliary vessels and could be safer than resection when managing strabismus in patients with a high risk of anterior segment ischemia [5].

When compared with routine resection surgeries, plication has no risk of muscle loss, is potentially reversible, has a relatively simple learning curve, requires less surgical time, and induces less surgical trauma, hemorrhage, and inflammation [6, 7]. To our knowledge, there are no clinical data comparing the surgical outcomes of plication and resection in managing strabismus in our region.

We compared the success rates and changes in degree of ocular deviation using plication versus resection combined with antagonist muscle recession in managing horizontal strabismus.

METHODS

This retrospective study compared the outcomes of plication with recession (group I) and resection with recession (group II) in management of horizontal strabismus by a single surgeon using a consistent technique. The study was conducted between January 2021 and August 2023 in accordance with the ethical principles outlined in the Declaration of Helsinki and was approved by the Institutional Review Board of Dhahran Eye Specialist Hospital, Dhahran, Saudi Arabia. Informed consent was obtained from all participants or their legal guardians before surgery and data collection. Patient confidentiality was maintained throughout the study, and all data were anonymized for analysis.

The inclusion criteria were diagnosis of horizontal strabismus, absence of neurological disorders, a minimum follow-up duration of 6 months, and performance of rectus muscle plication or resection. We excluded individuals with a history of strabismus surgery on the involved rectus muscle; with oculomotor or abducens nerve palsy; with abnormal eye muscles due to thyroid eye disease, Duane syndrome, chronic progressive external ophthalmoplegia, or scleral buckle surgery; with vertical muscle involvement; and with plication using adjustable suture technique.

All individuals underwent a detailed baseline eye and ocular motility evaluation. A through ocular examination was performed using a PSL Classic Portable Slit Lamp (Keeler, Windsor, UK), and an orthoptic assessment was performed using an alternating prism cover-uncover test to measure the angle at primary position, 30 cm, and 6 m, with and without glasses. The Krimsky method was used in patients with poor fixation. Manifest refraction was performed followed by cycloplegic refraction after instillation of cyclopentolate hydrochloride 1%, tropicamide 1.0% (Mydriacyl; Alcon, Puurs, Belgium), and phenylephrine 2.5% (Mydfrin; Alcon, TX, USA) 3 times at 10-min intervals, waiting half an hour until refraction.

In the resection group, a limbal incision was made to access the rectus muscle of interest. The muscle was identified and isolated using a series of muscle hooks. The point of resection was marked on the muscle, and double-armed absorbable Vicryl sutures (6-0 Vicryl; Ethicon Inc., Somerville, NJ, USA) were used to secure the muscle just posterior to the resection mark, using locking bites at the sides. After resection, the muscle portion was reattached to the original insertion. The conjunctival incision was closed using absorbable Vicryl sutures (8-0 Vicryl; Ethicon Inc.).

In the plication group, a limbal incision was made through the conjunctiva down to the bare sclera. The rectus muscle of interest was then identified and isolated using a series of muscle hooks, followed by blunt dissection of muscle from the fascial attachments and intermuscular septum. The point of plication was marked on the muscle. The muscle was then secured with double-armed absorbable Vicryl sutures (6-0 Vicryl; Ethicon Inc.), with locking bites at the sides. The muscle was re-sutured with a scleral bite at the original insertion, then folded, and the suture was finally tightened and secured. The conjunctival incision was closed as above.

For the antagonist muscle recession in both groups, a limbal incision was made in the conjunctiva down to the bare sclera. The rectus muscle of interest was then isolated using a muscle hook, and the muscle was bluntly dissected from the fascial attachments and intermuscular septum. The muscle was then secured at its insertion with double-armed absorbable Vicryl sutures (6-0 Vicryl; Ethicon Inc.), with locking bites at the sides. The muscle was detached from the sclera and re-sutured at the desired position posterior to original insertion. The conjunctival incision was closed as above.

Demographic and clinical data were collected from medical records, including age, sex, type of preoperative strabismus (exotropia or esotropia), baseline visual acuity, mean follow-up duration, laterality of operated eye, surgical doses of correction (resection, plication, or recession) in millimeters, preoperative strabismus magnitude in PD, and postoperative strabismus magnitude in PD. The successful postoperative deviation defined as ≤10 prism diopters (PD) [7] in primary position with under- or overcorrection.

Statistical analyses were conducted using IBM SPSS for Windows (version 22, IBM Corp., Armonk, NY, USA). To determine the normality of data distribution, the Shapiro–Wilk test was employed. Quantitative data were summarized using means and standard deviations (SDs), whereas qualitative data were summarized using frequencies and percentages. Comparison between groups was accomplished using the chi-squared test, independent *t*-test, or Mann–Whitney U test where applicable. A 10% difference in success rate was considered clinically meaningful, and statistical analysis aimed to detect any difference between groups. A P-value < 0.05 was considered statistically significant.

RESULTS

Forty-four patients were enrolled: 19 patients in group I (plication) and 25 patients in group II (resection). The mean (SD) follow-up durations for groups I and II were 9.8 (12.3) months and 14.6 (12.2) months, respectively. Group I comprised 15 unilateral and 4 bilateral cases of strabismus, whereas group II had 19 unilateral and 6 bilateral cases.

Table 1 lists the comparable ages, sex ratios, types of strabismus, and preoperative and postoperative angles of deviation between groups (all $P > 0.05$) (Table 1). Esotropia comprised 21 patients (10 in plication and 11 in resection group), and exotropia comprised 23 patients (9 in plication and 14 in resection group). Postoperatively, the numbers of patients with orthotropia, exotropia, and esotropia in group I were 14 (73.7%), 4 (21.0%), and 1 (5.3%), respectively, and in group II were 14 (56.0%), 8 (32.0%), and 3 (12.0%), respectively.

Ocular alignment was comparable between the plication and resection groups in total and in each subtype of strabismus (all $P > 0.05$). Despite comparable success rates between groups (73.7% in group I versus 64.0% in group II, $P > 0.05$) (Table 2), the difference (9.7%) was marginally close to the predefined clinically meaningful difference of 10%. In the esotropia subgroup, despite comparable alignments in the plication and resection groups ($P > 0.05$) (Table 2), the difference was clinically meaningful (17.3%), and both groups had a higher success rate in the esotropia subtype compared with that of exotropia (Table 2). The rates of over- or undercorrection were not statistically or clinically different in total and in each subtype of strabismus (all $P > 0.05$) (Table 2). No significant difference was found between groups in the success rates of unilateral (n = 11, 73.3% in group I versus n = 12, 63.2% in group II) or bilateral cases (n = 3, 75.0% in group I versus n = 4, 66.7% in group II) (both $P > 0.05$). Table 3 displays the comparable changes in angle of deviation in individuals with esotropia or exotropia between groups (both $P > 0.05$).

Table 1. Demographic and clinical characteristics of study groups

Variables	Group I (n = 19)	Group II (n = 25)	*P*-value
Age (y), Mean ± SD	6.1 ± 7.8	5.5 ± 7.2	0.803
Sex (Male / Female), n (%)	11 (57.9) / 8 (42.1)	13 (52.0) / 12 (48.0)	0.711
Type of strabismus (Esotropia / Exotropia), n (%)	10 (52.6) / 9 (47.4)	11 (44.0) / 14 (56.0)	0.570
Preoperative angle of deviation in esotropia (PD), Mean ± SD (Range)	36 ± 17 (20 to 80)	35 ± 8 (20 to 45)	0.522
Preoperative angle of deviation in exotropia (PD), Mean ± SD (Range)	29 ± 8 (20 to 40)	34 ± 9 (20 to 50)	0.279
Postoperative angle of deviation at the last follow-up visit in esotropia (PD), Mean ± SD (Range)	40	14 ± 10 (2 to 20)	0.500
Postoperative angle of deviation at the last follow-up visit in exotropia (PD), Mean ± SD (Range)	19 ± 2 (16 to 20)	21 ± 12 (6 to 43)	0.461
Postoperative angle of deviation at the last follow-up visit in orthotropia (PD), Mean ± SD (Range)	0 ± 0 (0 to 0)	1 ± 2 (0 to 6)	> 0.99

Abbreviations: n, numbers of participants; y, years; SD, standard deviation; %, percentage; PD, prism diopter. Note: group I, patients with strabismus who underwent plication of horizontal rectus muscle coupled with recession of antagonist muscle; group II, patients with strabismus who underwent resection of horizontal rectus muscle coupled with recession of antagonist muscle.

Table 2. Surgical success rates in study groups

Variable	Group I (n = 19)	Group II (n = 25)	*P*-value
Success rate, n (%)			
Total	14 (73.7)	16 (64.0)	0.495
Esotropia	9 (90.0)	8 (72.7)	0.314
Exotropia	5 (55.6)	8 (57.1)	0.940
Undercorrection, n (%)			
Total	5 (26.3)	8 (32.0)	0.682
Esotropia	1 (10.0)	2 (18.2)	0.593
Exotropia	4 (44.4)	6 (42.9)	0.940
Overcorrection, n (%)			
Total	0 (0)	1 (4.0)	0.378
Esotropia	0 (0)	1 (9.1)	0.329
Exotropia	0 (0)	0 (0)	> 0.99

Abbreviations: n, numbers of participants; %, percentage. Note: group I, patients with strabismus who underwent plication of horizontal rectus muscle coupled with recession of antagonist muscle; group II, patients with strabismus who underwent resection of horizontal rectus muscle coupled with recession of antagonist muscle.

Table 3. Comparison of changes in angle of deviation in operated exotropia or esotropia between study groups

Type of strabismus	Type of surgery	Surgery in mm	Type of surgery	Surgery in mm	Preoperative deviation (PD)	Postoperative deviation (PD)	Change in deviation (PD)	*P*-value
Esotropia, Mean ± SD								
Group I	LR plication	6.2 ± 2.0	MR recession	4.9 ± 1.1	36 ± 17	4 ± 13	32 ± 8	0.326
Group II	LR resection	6.9 ± 1.6	MR recession	4.9 ± 1.6	35 ± 8	8 ± 14	27 ± 16	
Exotropia, Mean ± SD								
Group I	MR plication	5.2 ± 1.6	LR recession	7.1 ± 1.7	29 ± 8	8 ± 10	21 ± 10	0.474
Group II	MR resection	5.7 ± 0.8	LR recession	7.9 ± 1.6	34 ± 9	8 ± 11	25 ± 16	

Abbreviations: mm, millimeters; PD, prism diopter; LR, lateral rectus muscle; SD, standard deviation; MR, medial rectus muscle. Note: group I, patients with strabismus who underwent plication of horizontal rectus muscle coupled with recession of antagonist muscle; group II, patients with strabismus who underwent resection of horizontal rectus muscle coupled with recession of antagonist muscle.

DISCUSSION

In this comparative study, patients achieved similar success rates using plication or resection combined with similar mean amounts of antagonist muscle recession. We included 44 patients; 19 and 25 patients underwent plication and resection respectively, with a mean (SD) follow-up duration of 9.8 (12.3) and 14.6 (12.2) months, respectively. Esotropia comprised 21 patients (10 in plication and 11 in resection group), and exotropia comprised 23 patients (9 in plication and 14 in resection group). Postoperatively, esotropia was detected in 4 patients (1 in plication and 3 in resection group), exotropia in 12 patients (4 in plication and 8 in resection group), with similar numbers of patients being orthotropic (14 patients in each group). The final success rates and mean changes in angle of deviation were comparable between the overall plication and resection groups, as well as between subgroups with each strabismus subtype. Likewise, the difference in rate of over- or undercorrection between groups was not statistically or clinically significant. Considering clinical significance, the success rate was 17.3% higher in the esotropia subgroup with plication than in the subgroup with resection. The esotropia subgroup achieved numerically a higher success rate compared with that of exotropia in both groups. Laterality of strabismus conferred no significant difference in success rates in either group.

Huston et al. [8] compared the success rates of plication and resection combined with antagonist muscle recession in 162 patients with basic esotropia and 60 patients with basic exotropia. At the 1–4-month postoperative examination, the success rates for plication in esotropia and exotropia were 95.5% and 77.4%, respectively; for resection, the rates were 89.2% and 96.6%, respectively. As in our study, success rates were comparable for esotropia and exotropia in the plication compared with resection group. Also similar to our results, they found no statistically significant difference in mean change of ocular alignment for medial rectus plication versus resection or lateral rectus plication versus resection [8].

In a retrospective review of medical records of patients who underwent resection or plication over 5 years, Alkharashi and Hunter [9] found a significantly higher success rate in resection (89%) than in plication (58%) at 6–12 weeks and a final follow-up of 3–56 months. In addition, the reoperation rate was significantly higher in the plication group (12.5%), with no reoperations in the resection group. They included individuals in a wide age range—children, adults, and older adults [9]—whereas we included participants <26 years of age; this may explain the observed differences between the two studies. However, this reasoning must be verified in further longitudinal studies that include individuals with basic esotropia and exotropia, comprising different age groups, to identify possible age-related differences in success rates between plication and resection surgery.

Mojon [10] introduced plication via minimally invasive strabismus surgery and observed no significant difference in final alignment or other visual and refractive outcomes compared with the traditional limbal approach [10]. The current study had comparable success rates for plication and resection as observed in previous studies [4, 8, 11]. Because of this, further studies using minimally invasive strabismus surgery comparing plication to resection could establish the safety of combined plication and minimally invasive surgery, especially in children with a compromised ocular surface or anterior segment.

Chaudhuri and Demer [4] conducted a retrospective, comparative study of eyes with esotropia (13 patients in plication group and 12 patients in resection group) or exotropia (9 patients in plication group and 19 patients in resection group) with a mean (SD) age of 28 (24) years, comparing postoperative binocular alignment after plication or resection at the first and final follow-up visits. They observed comparable early and late effects for plication and resection. They also reported plication as cosmetically acceptable and associated with minimal surgical trauma [4]. In agreement with their findings, we observed no significant difference between groups in success rates and final ocular alignment with esotropia or exotropia. However, the current study failed to assess the cosmetic acceptance of either procedure among participants. Further studies assessing patient satisfaction rates and the cosmetic effects of strabismus surgeries, along with objective measurements such as ocular alignment, could shed light on the subjective acceptability of these procedures.

None of our participants developed anterior segment ischemia up to the last follow-up visit. Likewise, in a prospective study [5] using postoperative iris angiography to investigate ciliary vessels in 8 patients with a mean (SD) of age 59.0 (13.3) years and 6 patients aged 58.2 (16.8) years who underwent plication or tenotomy, respectively, the authors confirmed the safety of plication in sparing ciliary vessels [5].

Issaho et al. [7] conducted a systematic review and meta-analysis with inclusion criteria of a minimum 6-month follow-up and success rate defined as a postoperative alignment within 10 PD orthotropia. Seven original studies were included, with a total of 322 patients in the plication group and 380 patients in the resection group. No significant difference in success rates, undercorrection, or mean degree of correction in PD was found between groups. The authors inferred that plication could be an alternative to resection in horizontal strabismus surgery; however, further clinical trials were deemed necessary for a robust conclusion [7]. Rajavi et al. [11] compared the success rate of plication (24 patients with exotropia) to that of resection (28 patients with exotropia) in a prospective randomized clinical trial with up to 6 months of follow-up. Finding comparable rates of surgical success for plication (87%) and resection (89.3%), and comparable reoperation rates (13% in plication and 10.7% in resection), they proposed plication as an effective alternative to resection in patients with exotropia [11]. Likewise, we found comparable success rates in the subgroup of patients with exotropia and similar mean changes in ocular deviation at mean (SD) follow-up durations of 9.8 (12.3) months and 14.6 (12.2) months in the plication and resection groups, respectively.

In assessing long-term outcomes of resection (114 patients) and plication (72 patients) combined with antagonist muscle recession in children with intermittent exotropia at 2 years' follow-up, Lee and Kim [12] observed a significantly higher success rate in resection (55.3%) than in plication (27.8%) [12]. However, in a retrospective review of 45 adult patients with intermittent exotropia, despite a significantly higher success rate in plication (89%) than in resection (72%) at the 1-week early postoperative visit, comparable outcomes (67% versus 60% in plication and resection, respectively) were noted at 12 months' follow-up [13]. Leffler [14] proposed that the extent of postoperative follow-up and compliance with follow-up are important to assure accurate estimation of success rate. Providing accurate reoperation rates for resection and plication within 12–24 months is recommended to estimate a reliable success rate for both surgical procedures [14]. This may indicate the significance of follow-up duration for estimating surgical success rates in plication and resection groups. This is also supported by the results of a recent meta-analysis including those having a minimum follow-up of 6 months, which found comparable postoperative alignment for both procedures [7].

In a prospective randomized trial [15] involving patients with convergence insufficiency type of intermittent exotropia (27 patients in plication and 28 patients in resection group) with mean (SD) ages of 10.4 (6.6) and 9.1 (5.6) years in the plication and resection groups, respectively, the surgical success rates at the 1-month (89% in plication or resection) and 6-month follow-up (64% in plication and 62% in resection) were comparable [15]. Sukhija and Kaur [16] recruited 28 patients with basic comitant exotropia without vertical pattern who underwent plication (13 patients) or resection (15 patients). They found comparable postoperative deviation and abduction limitation in both groups at 1 month postoperatively. Ultrasound biomicroscopy enabled the authors to identify and quantify plication in all operated eyes, and use of this device was recommended to identify and objectively measure the characteristics of plication [16]. Our outcomes were similar to those of previous studies [15, 16] in exotropic strabismus subgroups; however, we did not apply paraclinical image acquisition to replicate our objective findings in clinical examination. Further studies combining clinical assessment and paraclinical evaluation could provide more practical evidence on the efficacy and safety of plication and resection in managing childhood strabismus.

Our study found comparable effects for plication and resection in managing horizontal strabismus. However, the study is limited by its small sample size in both the resection and plication groups and its lack of randomized allocation. This may introduce selection bias and limit the generalizability of the current findings to diverse and large populations. However, a strength of this study is its use of a single surgeon using a consistent technique in all participants. Furthermore, to our knowledge, this was the first study on this topic—which supports the outcomes of previous studies—that has been conducted in the Eastern Province of Saudi Arabia. The use of artificial intelligence (AI) in various ocular diseases is considerable and widely expanding, offering the potential to enhance screening, diagnosis, treatment, and patient care. Multiple deep-learning programs have established high sensitivity and specificity in ocular diseases, from management to patient rehabilitation and education [17, 18]. Given the recent publication on the usefulness of AI-based apps for objective evaluation and classification of ocular motility [19], and the role of AI-based platforms in the diagnosis, angle evaluation, and surgical planning for strabismus [20], further studies could evaluate the potential of AI in the accurate assessment of success rates after strabismus surgery.

CONCLUSIONS

We found comparable success rates and postoperative alignment for the esotropic and exotropic types of strabismus managed using plication or resection combined with antagonist recession. These findings may encourage clinicians to apply plication as a less aggressive procedure in managing strabismus. However, further large-scale, longitudinal studies in a broad range of age groups using random allocation and employing paraclinical measurements along with clinical and subjective evaluation could provide practical evidence on the suitability of plication in managing various types of strabismus.

ETHICAL DECLARATIONS

Ethical approval: This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki and was approved by the IRB) of Dhahran Eye Specialist Hospital, Dhahran, Saudi Arabia. Informed consent was obtained from all participants or their legal guardians before surgery and data collection. Patient confidentiality was maintained throughout the study, and all data were anonymized for analysis.
Conflict of interest: None.

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