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Extraocular muscle resection, recession length and surgery outcome modelling in strabismus treatment: a pilot study

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Background Many surgical formulas have been developed and proposed based on the experience of surgeons to improve the predictability of strabismus surgery. However, the consent among strabismus surgeons regarding the dose effect of the extraocular muscle (EOM) recession or resection was not achieved yet and the disagreement about the appropriate amount of strabismus surgery still exists.
Objective Our study aimed to propose an instrument for EOM resection (RsL) and recession length (RcL) estimation before the surgery and second to elaborate an postoperative angle of deviation (PAD) predictive model using simple potential predictors.
Methods and Analysis The analytical prospective clinical study was conducted from April 2016 to July 2019, on a sample of 216 patients (aged between 2–58) with concomitant strabismus who underwent strabismus surgery in Clinical Republican Hospital 'Timofei Mosneaga'and Children Hospital 'Em Cotaga' from Republic of Moldova. The correlations of patients' age, strabismus type, amblyopia degree, RsL, RcL, preoperative angle of deviation (PreAD) with PAD were estimated using Pearson's correlation analysis. Multiple linear regression analysis, multicollinearity analysis and residual analysis were performed.
Results The EOM RsL was predicted using strabismus type, patient's age, PreAD and EOM RcL. EOM RcL, in turn, was estimated by the similar covariates set, instead of RcL being RsL. PAD modelling showed the PreAD, EOM RsL and EOM RcL predictive ability for strabismus surgery outcome prediction.
Conclusion In our study, we propose four mathematical models as potential instruments for EOM RsL, EOM RcL and PAD modelling in esotropia and exotropia surgery.

Significance of the study

What is already known about this subject?

- In order to improve the predictability of strabismus surgery, many surgical dose tables have been developed and proposed based on the experience of surgeons. However, it is still difficult to predict strabismus surgery outcome with certainty. Moreover, which preoperative factors are predictive of this success are still unclear.

What are the new findings?

- Four mathematical models as potential instruments for extraocular muscle (EOM) resection length, EOM recession length and postoperative angle of deviation modelling in esotropia and exotropia surgery were developed.

How might these results change the focus of research or clinical practice?

- We propose just a way for horizontal strabismus surgical treatment optimisation, a step forward to a person-centred medicine and with this study we would like to encourage the researchers to improve these models by finding more predictors and validation in a larger research.

INTRODUCTION

Strabismus affects approximately 4% of the population and can significantly affect the health-related quality of life of adults and children in various ways, including psychosocial and functional aspects.[1–5] The main goal of strabismus surgery is to correct misaligned eyes and improve binocular vision. Therefore, the predictability of the surgical outcome depends on the assessment of the factors that might influence the outcome of the strabismus surgery. There is no consensus on which factors are most important in predicting motor and functional surgery outcome.[6–8] Gräfe *et al*[9] were the first who mentioned the dose–response relationship in strabismus in 1857 and von Pflugk[10] followed his ideas using the degree/mm ratio based on the notion that 5° equals 1.1 mm on the surface of the globe. Since then, a lot of surgical formulas and tables have been developed and proposed to grow the predictability of strabismus surgery. However, there is still no consensus among strabismus surgeons on the dosage effect of recession or resection of extraocular muscles (EOM), and there is still disagreement about how much surgery is required for different types and degree of strabismus. Thus, our study aimed to provide (1) a tool for estimating the length of EOM resection, (2) a tool for estimating the length of EOM recession, (3) a predictive model for the postoperative angle of squint using simple possible predictors, confirmed by correlation analysis. We estimated that using simple predictors we can assess the length of EOM resection and recession, as well as strabismus surgery outcome.

MATERIALS AND METHODS

Study design

This was an analytical prospective clinical study conducted from April 2016 to June 2019 in a plot of 216 patients (aged between 2 and 58) with concomitant strabismus who underwent horizontal strabismus surgery in the Clinical Republican Hospital 'Timofei Mosneaga' and Children Hospital 'Em Cotaga', the Republic of Moldova was included in this study. The inclusion criteria were patients with horizontal concomitant manifest strabismus (normal eye movements and same angle of deviation in each direction of gaze) who underwent a strabismus surgery within the study period. The exclusion criteria were (1) a pre-existing eye disease such as corneal opacity, cataract, congenital optic atrophy or glaucoma; (2) incomitant strabismus; (3) patients who refuse to take part in the research. Patients with less than 6 months after surgery intervention follow-up period were also excluded. Data collection and analysis included: age at the time of surgery, gender, type of strabismus, preoperative and postoperative deviation angle of squint at 6 months follow-up (in PD), EOM recession and recession length (RcL) (in mm), lateral rectus muscle (LRM) and medial rectus muscle (MRM) tendon width and distance of insertion from the limbus, measured with a Castroviejo calliper (in mm). All patients underwent a full ophthalmic and orthoptic exam before the surgical correction. The prism cover test was used in order to measure the angle of deviation for both far (6 m) and near (30 cm) fixation with an appropriate optical correction. The preoperative and postoperative deviation was measured by the cover–uncover test, simultaneous prism cover test and, under total dissociation by the alternating prism cover test, to rule out any sensory effect on the angle of deviation. A standard set of loose plastic prisms was used for all measurements. The plastic prisms were held in front of the deviating eye and an alternating cover test performed. The test was continued until a prism was found which just produced a movement in the opposite direction. The value of the prism prior to this overcorrecting prism was taken to represent the amount of deviation, and its value recorded. Each prism cover test (PCT) was repeated and if the measurements were inconsistent, the mean of the two values was then recorded.[11–13]

Based on the best-corrected acuity of the amblyopic, eye mild amblyopia was classified as Best corrected visual acuity (BCVA) of 20/25 - 20/40, moderate as BCVA of 20/40 - 20/100 and severe as BCVA of ≤20/100. Surgeries were performed by the same doctor, with the patient under general anaesthesia (patients ≤18 years of age) or local anaesthesia (patients ≥18 years of age). The amount of strabismus surgery was based on ocular alignment in primary gase at distance. EOM rectus recession, resection or recession–resection procedures were performed. Successful result was determined as final alignment within ±10 PD of straight, with or without evidence of binocular single vision as were proposed in the study by Ehrenberg *et al*.[14] Written informed consent was taken compulsory from all the participants and from parents and/or legal guardians of patients under the age of 18 prior to the enrolment in the study. Participants and researchers did not receive any financial compensation.

Statistical analysis

Statistical analysis was accomplished by using SPSS V.26 program and a p value < 0.05 was considered statistically significant. Qualitative evidences were expressed in percentages with a 95% CI. Quantitative variables were tested for distribution using the Shapiro-Wilk test. The correlations of patients' age, strabismus type (ET was labelled as 1 and XT as 2), EOM RcL, EOM resection length (RsL), PreAD with postoperative angle of deviation (PAD), tendon length insertion (potential efficient variables) were estimated using Pearson's correlation analysis.

Multiple stepwise linear regression analysis with the purpose of the coefficient estimation, multicolliearity analysis (Tolerance) and residual analysis were performed in order to predict the primary outcome (treatment results) and for RsL/RcL modelling. The estimated factor, in turn, was used to mathematically express the identified form of association.

RESULTS

The study plot consisted of 216 patients diagnosed with concomitant strabismus, 160 patients with esotropia and 56 with exotropia. The average age was 10.5 years. Patients' demographics and clinical characteristics are summarised in online supplemental table 1.

Esotropia surgery results modelling

Correlation analysis named to identify potential predictors for esotropia surgery outcome revealed the following significant associations with preoperative angle of squint (p≤0.001, effect size=0.06), amblyopia degree (p≤0.001 (effect size=0.32) and EOM recession amount (p=0.24, effect size=0.31) (online supplemental table 2).

All the relationships found were taken into account for the multivariate analysis to simulate the postoperative esotropia outcome. A stepwise multivariate regression model revealed that PreAD. EOM RsL and EOM RcL contributes meaningful information in the prediction of esotropia surgery outcome. (F=343.82. p<0.001) (table 1). Moreover, the adjusted R^2=0.87 (the model explains 87% of the surgery outcome variance in esotropia).

The final model included the following parameters:

- Constant (B=−13.43; p<0.001).
- Preoperative deviation (B=0.85; p<0.001).
- EOM RcL (B=−0.52; p=0.01).
- EOM RsL (B=−1.01; p<0.001).

Table 1 Efficient variables for esotropia surgery outcome prediction model

	Unstandardised coefficients		Standardised coefficients			95% CI for B		Collinearity statistics
	B	SD	Beta	T	Sig.	Lower bound	Upper bound	Tolerance
(Constant)	–13.43	1.13		–11.86	<0.001	–15.67	–11.19	
Preoperative angle	0.85	0.03	0.98	31.27	<0.001	0.8	0.91	0.85
EOM recesion amount (mm)	–0.52	0.2	–0.10	–2.68	0.01	–0.91	–0.14	0.56
EOM resection amount (mm)	–1.01	0.12	–0.33	–8.24	<0.001	–1.26	–0.77	0.53

Multivariate analysis.
EOM, extraocular muscle; Sig., significance.

The other parameters were irrelevant and were therefore not included in the final forecast model. The following mathematical expression was obtained:

Esotropia surgery outcome=–13.43 + 0.85* PreAD (PD) - 1.01* EOM RcL (mm) - 0.52 *EOM RsL

The collinearity analysis showed that the prediction quality was not affected by the potential strong link between the model parameters (tolerance being higher than 0.1 and lower than 10, respectively). From a quantitative point of view, it was demonstrated by the coefficients standardisation that the preoperative amount of deviation (beta=0.98) is the most important predictor followed by the EOM resection amount (beta=–0.33) and the EOM RcL (beta=–0.10).

Exotropia surgery outcome modelling

Correlation analysis of exotropia strabismus surgical treatment outcomes were correlated with the (p<0.001; effect size=0.6), age at surgery (p<0.011, effect size=0.52); EOM RcL (mm) (p=0.015, effect size=0.34), EOM RsL (p<0.001), effect size=0.3), LRM and MRM insertion distance (p=0.01, effect size=0.39 and p=0.021, effect size=0.43) (online supplemental table 3).

A stepwise multivariate regression model revealed that PreAD EOM RcL and EOM RsL contributes meaningful information in the prediction of postoperative outcome, (F=299.95, p<0.001) (table 2). Moreover, the adjusted R^2=0.92 depicted that the model explain 92% of the variance in the postoperative outcome. The null hypothesis (none of the parameters included in the model can predict the postoperative angle value at 6 months follow-up) was rejected (p<0.001).

The final model included the following features:

- Constant (B=–15.08; p<0.001).
- Preoperative deviation (B=0.80; p<0.001).
- EOM recession amount (B=–0.52; p=0.007).

The following mathematical expression was obtained:

Exotropia postoperative surgery outcome=–15.08+ 0.80*preoperative angle – 0.52* EOM resection amount.

The collinearity analysis showed that the forecast quality was not influenced by the potentially strong relation between the model parameters (tolerance was above 0.1 and below 10, respectively). The coefficients standardisation analysis revealed that the preoperative amount of deviation (beta=1.01) is the most important predictor for postoperative outcome followed by the EOM recession amount (beta=–0.12).

The correlation analysis of the factors associated with postoperative drift after 6 months of follow-up is shown in table 3.

EOM RsL prediction

Correlation analysis named to identify potential predictors revealed the following significant associations with EOM RsL: preoperative angle of squint (p≤0.001, effect size 0.23), strabismus type (p≤0.001, effect size=0.22) and age of surgery (p≤0.001, effect size=0.15) as well as LRM and LRM distance insertion from the limbus (p≤0.001,

Table 2 Efficient variables for exotropia treatment results modelling

	Unstandardised coefficients		Standardised coefficients			95% CI for B		Collinearity statistics
	B	SD	Beta	T	Sig.	Lower bound	Upper bound	Tolerance
(Constant)	–15.08	1.26		–11.98	<0.001	–17.61	–12.56	
Preoperative angle	0.80	0.03	1.01	23.06	<0.001	0.72	0.82	0.80
EOM recession amount (mm)	–0.52	0.19	–0.12	–2.72	0.007	–0.9	–0.15	0.80

Multivariate analysis.
EOM, extraocular muscle; Sig., significance.

Table 3 Potential predictors for postoperative outcome, resection and recession length by correlation analysis for the whole sample (r Pearson, 95% CI)

	Postoperative deviaton	Preoperative deviation	Age	Strabismus type	Amblyopia degree	EOM recession (mm)	EOM resection (mm)	LRM tendon width	MRM tendon width	LRM insertion	MRM insertion
Postoperative deviation	1	0.91* 0.88, 0.93	0.13 −0.02, 0.28	0.12 −0.01, 0.26	0.21* 0.08, 0.35	0.23* 0.11, 0.33	0.16† 0.02, 0.29	0.08 −0.04, 0.2	0.09 −0.03, 0.22	0.11 −0.03, 0.26	0.14† −0.00, 0.28
Preoperative deviation		1	0.29* 0.14, 0.42	0.21* 0.08, 0.34	0.29* 0.15, 0.43	0.20* 0.08, 0.32	0.36* 0.24, 0.47	0.074 −0.06, 0.2	0.14† 0.02, 0.28	0.17* 0.04, 0.32	0.09* 0.06, 0.33
Age			1	0.59* 0.49, 0.69	0.17† 0.03, 0.31	0.05 0.19, 0.09	0.64* 0.56, 0.71	0.14† −0.01, 0.29	0.02 −0.09, 0.14	0.41* 0.3, 0.52	0.42* 0.29, 0.53
Strabismus type				1	0.08 0.2, 0.05	0.03 −0.13, 0.18	0.49* 0.38, 0.6	0.16† 0.02, 0.3	0.03 0.15, 0.1	0.43* 0.31, 0.54	0.37* 0.24, 0.49
Amblyopia degree					1	0.03 −0.15, 0.21	0.18* 0.03, 0.31	0.03 −0.12, 0.18	0.19* 0.06, 0.33	0.11 −0.01, 0.23	0.08 −0.04, 0.2
EOM recession						1	0.44* 0.54,−0.33	0.07 −0.06, 0.19	0.07 0.21, 0.07	0.13 −0.01, 0.27	0.08 −0.06, 0.22
EOM resection							1	0.09 −0.05, 0.22	0.09 −0.05, 0.21	0.27* 0.16, 0.4	0.28* 0.16, 0.4
LRM tendon width								1	0.03 0.17, 0.11	0.19* 0.06, 0.31	0.13 0.01, 0.26
MRM tendon width									1	0.11 −0.02, 0.24	0.044 −0.1, 0.18
LRM insertion										1	0.81* 0.76, 0.86
MRM insertion											1

Nr = 216.
*Correlation is significant at the 0.01 level (two tailed).
†Correlation is significant at the 0.05 level (two tailed).
EOM, extraocular muscle; LRM, lateral rectus muscle; MRM, medial rectus muscle.

Table 4 Efficient variables for EOM resection length prediction model

	Unstandardised coefficients		Standardised coefficients			95% CI for B		Collinearity statistics
	B	SD	Beta	T	Sig.	Lower bound	Upper bound	Tolerance
(Constant)	–0.07	0.55		–0.14	0.89	–1.15	1.00	
Preoperative angle	0.09	0.01	0.3	7.19	<0.001	0.06	0.11	0.87
Strabismus type (Exotropia)	1.40	0.34	0.19	4.12	<0.001	0.73	2.07	0.65
Patient age	0.11	0.01	0.41	8.26	<0.001	0.08	0.13	0.61
EOM recession amount (mm)	–0.83	0.07	–0.48	–12.11	<0.001	–0.96	–0.69	0.94

Multivariate analysis.
EOM, extraocular muscle; Sig., significance.

effect size=0.24) and amblyopia degree (p≤0.001, effect size=0.28) (table 3). All the relationships found were taken into account for the multivariate analysis to simulate the preoperative EOM recession amount in mm. A stepwise multivariate regression model revealed that PreAD, patient age, strabismus type and EOM RcL contributes meaningful information in the prediction of preoperative EOM RsL, (F=112.31, p<0.001) (table 4). Moreover, the adjusted R^2=0.67 (the model explains 67% of the EOM resection amount variance).

The final model included the following parameters:

- Constant (B= -0,07; p=0.89).
- Strabismus type (exotropia) (B= 1.40; p<0.001).
- Patient age (B=0.11; p<0.001).
- Preoperative deviation (B= 0.09 ; p<0.001).
- EOM RcL (B=–0.83; p<0.001).

The other parameters were irrelevant and were therefore not included in the final forecast model. The following mathematical expression was obtained:

EOM RsL= -0.07 + 1.40* strabismus type (exotropia) +0.11*patient age +0.09* PreAD (PD) –0.83* EOM RcL.

The collinearity analysis showed that the prediction quality was not affected by the potential strong link between the model parameters (tolerance being higher than 0.1 and lower than 10, respectively). From a quantitative point of view, it was demonstrated by the coefficients standardisation that EOM RcL (beta=–0.48) is the most important predictor followed by the patient's age (beta=0.41), the preoperative amount of deviation (beta=0.3) and strabismus type (beta=0.19).

EOM RcL prediction

Correlation analysis, in order to identify the potential predictors, revealed a significant association of EOM RcL and PreAD (p=0.01, effect size=0.24 and EOM RsL (p≤0.001, effect size=0.2) (table 3). All the relationships found were taken into account for the multivariate analysis to simulate the preoperative EOM recession amount in mm. A stepwise multivariate regression model revealed that the PreAD, patients' age, type of strabismus and EOM RsL remained significant predictors for preoperative EOM recession estimation (table 5) (F=42.05, p<0.001). Moreover, the Adjusted R^2=0.43 depicted that the model explains 43% of the variance in the EOM recession amount.

The final model included the following parameters:

- Constant (B=1.80; p<0.001).
- Strabismus type (exotropia) (B=0.9; p=0.001).
- Patient age (B=0.04; p=0.001).
- Preoperative deviation (B=0.07; p<0.001);
- EOM RsL (B=–0.5; p<0.001).

The other parameters were irrelevant and were therefore not included in the final forecast model. The following mathematical expression was obtained:

Table 5 Efficient variables for recession length prediction model

	Unstandardised coefficients		Standardised coefficients			95% CI for B		Collinearity statistics
	B	SD	Beta	T	Sig.	Lower bound	Upper bound	Tolerance
(Constant)	1.80	0.40		4.45	P<0.001	1.00	2.6	
Preoperative angle	0.07	0.01	0.39	7.08	P<0.001	0.05	0.09	0.86
Strabismus type (exotropia)	0.86	0.27	0.21	3.22	0.001	0.34	1.39	0.63
Age	0.04	0.01	0.26	3.49	0.001	0.02	0.06	0.49
EOM resection amount (mm)	–0.5	0.04	–0.84	–12.11	P<0.001	–0.58	–0.42	0.54

Multivariate analysis.
EOM, extraocular muscle; Sig., significance.

EOM RcL=1.80+0.9* strabismus type (exotropia) +0.04*patient age +0.07* PreAD (PD) − 0.5* EOM RsL.

The collinearity analysis showed that the prediction quality was not affected by the potential strong link between the model parameters (tolerance being higher than 0.1 and lower than 10, respectively). From a quantitative point of view, it was demonstrated by the coefficients standardisation that the EOM RsL is the most important predictor (beta=−0.84), followed by the preoperative amount of deviation (beta=0.39), the patient age (beta=0.26) and strabismus type (beta=0.21).

In addition, the developed models met the requirements for linear regression residuals.

DISCUSSIONS

Due to the large number of tables for the treatment of strabismus surgery and the factors that influence the outcome of strabismus surgery. This study was carried out on the one hand to identify an instrument for EOM resection and to assess the length of recession before surgery for strabismus provide, and on the other hand to develop a predictive model for the PAD using simple potential predictors highlighted by multivariate analysis.

Success rates of strabismus surgery tend to range from 35.6% to 93.3%, lower results being reported in cases were both, motor and functional outcomes, were taken into consideration.[7 15–19] However, direct comparison of success rates is difficult to be completed due to the variability in samples age, surgical procedures, lengths of follow-up period after surgery, definition of success among studies, etc.[20] Most researchers defined the motor surgery outcome successful as a postoperative deviation of 5–10 PD esotropia or 10–15 PD exotrophia.[16 21–24] Our success rate of 63% for horizontal strabismus was similar to the results reported by the other publication that used the same outcome criteria definition for a successful surgery.[16] Short-term studies within the first postoperative visit, till 6 months to 1-year follow-up reports a higher success rates (of approximately 80%), whereas studies with follow-up period over 2 years have shown a lower success rate (50%–60%).[7 25 26]

The aim of the strabismus surgery plan is to achieve an optimal motor and functional postoperative result for each individual patient. However, the surgical approach is controversial and variations in planned EOM recession and/or resection volume, as well as surgeons' approaches, may vary and be tailored to individual patients.

In this study, we evaluated the effect of 10 preoperative factors that we envisaged could affect the outcome of strabismus surgery. Our study revealed that preoperative deviation and the EOM RcL were the only factors significantly predictive of surgical success. A patient with smaller preoperative deviation (<40 PD) has better chances of getting a successful outcome. It was suggested that this is partly because small angle deviations can be more accurately measured than the large angle deviations.[16 27 28] Similar to our results Trigler and Siatkowski[29] and Kampanartsanyakorn *et al*[16] in their study also found that preoperative deviations of <30 PD was associated with successful surgery. On the contrary, Umazume *et al*[28] paradoxically found that higher value of preoperative distance deviation was associated with surgical success in horizontal strabismus.[28] Werther the absence of dense amblyopia was correlated with surgical success (p=0.001) the multivariate regression analysis did not revealed a significant functional relationship. Meanwhile, there seems to be little-published research discussing any association of amblyopia with successful outcome. Kumari *et al*[23] also found that the absence of dense amblyopia is associated with surgical success. Similarly, Yurdakul and Ugurlu[30] in a retrospective analysis of risk factors for consecutive XT found that amblyopia was significantly associated with development of consecutive XT. Type of strabismus was reported to influence the surgery treatment outcome, ET in contrast with XT beeing a factor significantly predictive of surgical success.[23 31] One possible explanation for lower success rate with exotropia compared with esotropia reported by some authors is the tendency of postoperative drift in the XT, especially in a setting of moderate to dense amblyopia.[23] In contrast, our study found no significant correlation between strabismus type and a successful motor outcome at 6-month postoperative period (p=0.09).

Studies on the association between age at surgery and response to surgery have shown mixed and conflicting results. We found no significant correlation between the age of the operation and the outcome of the operation after 6 months of the postoperative period (p=0.08). The outcome of surgery was similar in both young and old patients in our study as well in the studies reported by Repka *et al*[32]; Waheeda-Azwa *et al.*[18] In contrast to the above studies, Yam *et al*[22] demonstrated that the older age at surgery and longer interval between onset and surgery was associated with early surgical success that was explained by a more accurate measurement of preoperative deviation in older children.[18] The width of the extraocular tendon of the LRM was reported to be an indicator for assessing the impact of the recession of the lateral rectus on intermittent exotropia.[33–35] We did not found any correlation between LRM (p=0.33) and MRM (p=0.17) tendon width with a successful surgery outcome. However, a correlation was noticed between MRM and LRM insertion with a successful outcome in exotropia cases.

Recession and resection of the EOM is a classic technique used in strabismus treatment. Some researchers sustain that a recession does more than a resection, while the others believe the opposite idea is more accurate.[36 37] Kushner[38] mentioned that the dose–response curve for EOM recessions and resections are approximately similar.[38] Recommendations concerning EOM resection and recession amount vary widely.[38–41]

Our postoperative strabismus surgery outcome models revealed that for every additional EOM recession amount (mm) the expected EOM RsL decreases by 0.8 on average if all other variables are constant. For every additional patient age (in years) the expected EOM resection amount increases with 0.11 on average, with 0.09 for every additional preoperative deviation angle and with 1.4 for XT cases.

For every additional EOM resection amount (mm) the expected EOM RcL decreases by 0.5 on average, by holding all other variables constant. For every additional patient age (in years) the expected EOM recession amount increases with 0.04 on average, with 0.07 for every additional preoperative deviation angle and with 0.9 for XT cases.

In esotropia cases for every additional preoperative deviation degree, the expected postoperative amount of deviation increases by 0.85 on average, by holding all other variables constant. For every additional EOM resection amount (mm) the expected postoperative deviation decreases by 1.01 on average and for every additional EOM recession amount the expected postoperative deviation decreases by 0.52 on average by holding all other variables constant.

In exotropia cases for every additional preoperative deviation degree, the expected postoperative amount of deviation increases by 0.80 on average, by holding all other variables constant. For every additional EOM resection amount (mm) the expected postoperative deviation decreases by 0.52 on average.

Strengths and limitations of this study

This pilot study was an attempt to propose an instrument for EOM RsL and RcL estimation before the surgery and second to elaborate an PAD predictive model using simple potential predictors evidenced by correlation analysis. This study has some limits. First, the application of multiple regression analysis to the exotropia cases may be limited by variation in predictor variables according to sample population. Second, due to the fact that some correlation among the potential predictors can generate a multicollinearity problem in multivariate analysis we need to take into consideration the adjustment procedure. The success rate of strabismus surgery is multifactorial. As there are other variables that can influence the surgery outcome, such as the type of surgery (sensory status of the patient, bilateral recession of the rectus muscle vs unilateral recession–resection), high refractive errors, oblique muscle dysfunction or pattern of strabismus, the chosen anatomical features and surgical techniques, as well as the surgeon's experience, techniques such as differences in muscle exposure, suturing application, style of attachment, surgical volume measurement and, even proprioception disroption during strabismus surgery. [42–47] Identifying these factors can improve the surgery outcome and identify a group with long-term stable compliance. In addition, these models needs to be validated using an independent sample in the following studies. Finally, the proposed strategy, in our opinion, has good perspectives in order to have an efficient instrument for RsL/RcL determination and strabismus surgery outcomes improvement.

Implications

Taking into account the results and listed limitations, we plan to extend our research. The number of patients will be increased by performing a multicentral study. Other potential factors that could affect the the strabismus surgery outcome also will be taken into account. Finally, the results will be validated using an independent sample.

CONCLUSIONS

In our study, we propose three mathematical models as potential instruments for EOM RsL, EOM RcL and PAD modelling in strabismus surgery.

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Contributors AP and OA were involved in the design of the study; AP collected the data and is resposible for the overall content of the atricle; AP and OA analysed the data and wrote the manuscript; and EB, JRB and POL revised the manuscript. All authors read and approved the final manuscript. AP is the guarantor.

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