

Passive limitation of adduction after Cüppers's 'Fadenoperation' on medial recti

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SUMMARY In 40 eyes of 20 esotropic subjects in which a 'Fadenoperation' was performed on the medial recti we measured the resistance to ocular rotation in adduction before and after the operation. The difference between the two sets of force measurements demonstrates that the Fadenoperation on medial recti produces a mechanical restriction to adduction which can explain the effect of the surgical procedure on the strabismic deviation.

In 1974 Cüppers described the well known surgical procedure which he named 'Fadenoperation'.¹ The effect of the operation was at first attributed solely to the reduction of the tangential component of the muscle force produced by the posterior fixation.^{1,2} Later it was pointed out³ that several different mechanisms could interact and concur to produce the surgical effect:

- (1) the reduction of the rotational component of the force generated by the muscle;
- (2) the exclusion from activity of a contingent of the muscle fibres;
- (3) a stretching of the muscle owing to the fact that the scleral fixation increases the distance between the origin and the true insertion of the muscle if the true insertion remains in its original position;
- (4) a slack in the muscle fibres posterior to the fixation suture which occurs when the tightening of the suture is made while the muscle is stretched to provide adequate exposure⁴;
- (5) a mechanical restriction to ocular rotation in the field of action of the operated muscle^{5,6} produced by the connective tissue structures, which endeavour to maintain the physiological course of the muscle,³ or by a 'reverse leash' mechanism.⁷

All these hypothetical effects were derived from a theoretical analysis of the new mechanical situation

created by the surgical procedure, but so far none of them has been experimentally proved. The present investigation was aimed at ascertaining the existence and the importance of a mechanical restriction to ocular rotation produced by the Fadenoperation.

Materials and methods

In 40 eyes of 20 comitant alternating esotropic patients, in which a Fadenoperation was performed on both medial recti we measured the resistance to passive adduction before and after the operation. The most significant characteristics of the patients are listed in Table 1.

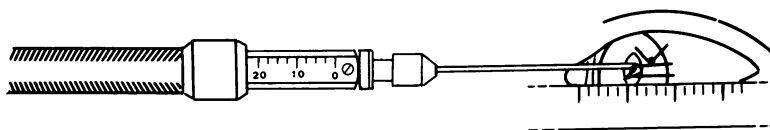
The posterior fixation sutures were placed 14 mm behind the insertion of the medial recti by a technique similar to that originally described by Cüppers.¹ A small recession of the medial recti was

Table 1 Summary of clinical data

Patients: 20 (M:6, F:14)	Eyes: 40
Onset of esotropia (months)	
median: 15	max: 96
min: 0	
Age at the operation (years, months)	
median: 3 yr 10 m	max: 11 yr 8 m
min: 2 yr 4 m	
Maximal ocular deviation at distance (degrees)	
median: 26	max: 38
min: 16	
Refraction (spherical equivalent, dioptres)	
median: +3.25	max: +6.25
min: -0.5	

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Fig. 1 The experimental set-up.



added in all procedures (3 mm in 16 muscles, 2 mm in 22 muscles, and 1 mm in 2 muscles). Before the operation, in the awake patient, we measured with a ruler the distance between the temporal limbus and the inner canthus when the eye was fixating in a straight ahead position, which we estimated to be a good approximation of the primary position.⁵

In stage 3, plane 2, of halothane general anaesthesia, which was induced without succinylcholine,⁸ we repeated the measurement of the same cantholimbus distance by the same method and at the same observation distance in order to control the paralactic error. In this way we could determine the position of the globe relative to the primary position.

A traction suture was passed through the temporal limbus and a knot made not too far away. The loop of this suture was then hooked with the hook attached to a modified Müller ophthalmodynamometer, previously gas sterilised, and a tangential traction was applied in order to produce a nasal rotation of the globe. A ruler held at the globe surface indicated the size of the nasal displacement of the temporal limbus. The grams of force required for each millimeter of temporal limbus displacement, up to 8 mm, was read by an assistant from the dynamometer (Fig. 1).

The globe was then replaced in the original position and a second set of measurements was obtained. The same procedure was carried out after the completion of the operation, but this time force measurements were recorded in primary position and at 2 mm intervals up to 8 mm of limbus displacement in adduction.

The ophthalmodynamometer was accurately calibrated before every surgical session.

Table 2 *Passive resistance to adduction (grams) before and after a Fadenoperation on 40 medial recti*

Adduction (mm)	Preop. mean (95% conf. limits)	Postop. mean (95% conf. limits)
0 (primary position)	0 (-)	14.87 (13.13-16.92)
2	4.36 (2.86-6.34)	20.22 (18.31-22.43)
4	10.53 (8.94-12.45)	25.90 (23.52-28.67)
6	13.36 (11.50-15.59)	36.80 (30.02-41.19)
8	18.41 (16.77-20.27)	52.15 (44.97-56.48)

To ascertain the effect of several variables on the resistance to passive adduction before and after the Fadenoperation on medial recti we used analysis of covariance for repeated measurements.⁹ This statistical technique combines the features of the analysis of variance and of regression. It was therefore possible jointly to evaluate the relationship between a continuous response variable and a set of independent variables measured on different scales. In our analysis we considered a mixture of continuous variables (age, onset, and duration of strabismus, pre- and postoperative ocular deviation, postoperative adduction); one 'grouping' factor (sex) and two 'within' factors, namely, the 'adduction' factor with five levels (0, 2, 4, 6, 8 mm of passive adduction) and the 'before and after' factor with two levels (before and after the Fadenoperation).

Rather than the original tension measurements the inverse of these values was employed in the analysis in order to render their distribution approximately gaussian. On the assumption that the distribution of the inverse of the tension values was gaussian, approximate 95% confidence limits were calculated both for the single means at each level of passive adduction and for their difference before and after the Fadenoperation. Back transformation of these values provided the estimates of the 95% confidence limits in the original scale.

The eye position at rest was considered free from error. This is why at this point there is no measure-

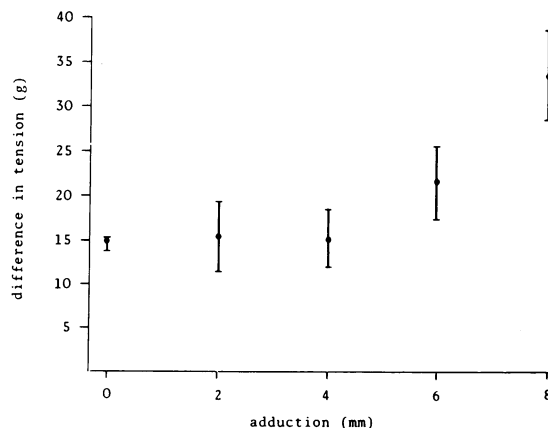


Fig. 2 *Estimated differences in tension (\pm 95% confidence limits) before and after Fadenoperation on 40 medial recti.*

ment of variability, and the 95% confidence limits could not be computed.

The P2V Program of the BMDP Statistical Package was used to perform the analysis.

Results

The results of our investigation are presented in Table 2 and Fig. 2. Only the 'within' factors 'adduction' and 'before and after' as well as their interaction proved to be highly significant ($p < 0.0001$). That means that the passive resistance to adduction was influenced by the Fadenoperation on medial recti in a way proportional to the degree of adduction.

The influence of the order independent variables could not be demonstrated at the $p = 0.05$ significance level.

Discussion

The preoperative measurements of passive adduction show a stiffness of about 0.45–0.5 g per degree of adduction. This compares favourably with the values reported in other studies^{8,10–12} and corroborates the accuracy of our measurement method.

The postoperative measurements show that the Fadenoperation on medial recti produces an augmentation of the passive resistance to adduction which increases with the degree of adduction. The measurements show that in order to keep the eye in the primary position, immediately after the operation, the extraocular muscles should develop a rotational force near to that needed preoperatively to rotate the eye to about 30° of adduction. This could account for the effect of the Fadenoperation in the primary position, which was never completely and satisfactorily explained by other mechanisms. This resistance could also be the cause of the transient divergence which is typically observed at the end of the operation and in the first postoperative days.

The passive resistance to adduction seems to run a decreasing course after the operation, since we usually observed a steady increase of the adduction in the postoperative months (from about 25° immediately after the operation to about 35°–40° after one year). This evolution could be explained by the reduction of the postoperative inflammatory reaction

as well as by a stretching of the connective structures in which the muscle is embedded.

From our study we can conclude that the mechanical restriction to ocular rotation produced by the Fadenoperation has a fundamental role in determining the effect of the operation on the strabismic deviation. In the introduction we mentioned other mechanisms proposed to show how the Fadenoperation could produce a reduction of the rotational force of the muscles. We acknowledge that they can concur to determine the effect of the operation, but we would emphasise that up to now their efficacy has not been experimentally proved.

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