A comparison of two different techniques for oculomotor torque reduction

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ABSTRACT.
Purpose: **To compare the results of two different surgical techniques: 'Cüppers technique', in which the torque of oculomotor rectus muscles is reduced by suturing the muscle to the globe in the posterior half of the globe; and 'Y-split recessions', in which the muscle torque is reduced by Y-splitting the rectus muscles, and reattaching the two halves at an angle to each other.**
Methods: **We carried out a retrospective analysis of the outcome of surgery on 100 patients with infantile esotropia.**
Results: **Both techniques show a sufficient reduction of strabismus angle variability, and minimal and maximal strabismus angle.**
Conclusions: **Both techniques achieve satisfactory results. In addition, the Y-split technique allows for accurate control of the muscle torque and requires no access to the posterior half of the eye, which can facilitate the surgical approach. For a reduction in muscle torque, the Y-split recession is a good alternative to the established Cüppers technique.**

Key words: strabismus – nystagmus – infantile esotropia – torque reduction

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Introduction

The contraction of an extraocular muscle exerts a torque on the eyeball. Some oculomotor pathologies can be treated by reducing this torque. As the torque is characterized by the formula $T = F*r$, there are two ways to achieve a torque reduction: one can either reduce the force F exerted by the muscle; or one can reduce the lever arm, r. Force reduction can be achieved by a number of techniques, such as bilateral maximal recession of the affected muscles (Leitch et al. 1990; Stager et al. 1994; Birch et al. 2004; Ruiz et al. 2004; Elliott & Shafiq 2005; Hemmerdinger et al. 2005). Here, we focus on the second option, the reduction of the lever arm r.

Currently, two surgical techniques are available: the 'Cüppers technique', which was first presented 40 years ago and is now well established (Cüppers 1956, 1961, 1966; Leitch et al. 1990; de Decker & de Decker 1998; Steffen et al. 1998). It achieves a reduction in the extraocular muscle torque by suturing the muscle to the posterior half of the globe (Fig. 1A). A number of studies have shown that this successfully reduces variable strabismus angle and nystagmus (Scott 1977; Helveston 1993; Clark et al. 1999). The severely position-dependent torque reduction of the Cüppers technique is assumed to be the main reason for the stabilization of the strabismus angle. However, the strong position dependence and the occurrence of radial forces for eccentric eye position have also been reported to occasionally cause side-effects such as globe retraction, globe motility reduction and retinal detachment (Cüppers 1956, 1966; Scott 1977; Helveston 1993; de Decker & deDecker 1998; Steffen et al. 1998; Clark et al. 1999).

A different surgical approach has been proposed. It involves Y-splitting an extraocular muscle into two halves and reattaching the two halves at an angle to each other, by which the effective lever arm of this muscle can be significantly reduced (Castanera

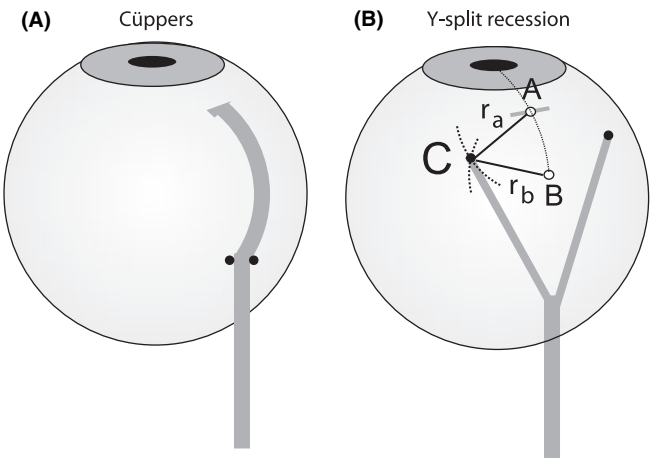

Fig. 1. Sketch of surgical technique. (A) Cüppers suture, 14 mm behind insertion. (B) Muscle split at a length of 15 mm, and reinserted at position C. Position A is the middle of the natural insertion and position B is 6 mm behind in a radial direction. The intersection of distance r_a, measured from point A, and distance r_b, measured from point B, indicates the new insertion point C. The same procedure is applied to the second muscle part.

1989; Roggenkamper 1989; Priglinger & Hametner 1994; Haslwanter et al. 2004; Hoerantner et al. 2004). We refer to this technique as 'Y-split recession' (Fig. 1B).

In the retrospective study presented here, we compare the results of the two techniques. The biomechanics of the two methods are quite different: whereas with Cüppers torque reduction is heavily dependent on eye position, it is fairly constant with Y-split recession. We hypothesized that the lower and constant torque reduction of the Y-split recession would be sufficient to stabilize the variable strabismus angle, while avoiding the known side-effects of the Cüppers technique. To test this hypothesis, we retrospectively compared two groups of patients who presented with infantile esotropia.

Infantile esotropia is an oculomotor disorder characterized by variable strabismus angle and nystagmus. The first group had been treated by Cüppers' technique and the second by Y-split recession.

Materials and Methods

Subjects

We tested 100 patients with infantile esotropia. For reasons described in detail in Table 1, we decided to substitute a surgical technique designated 'Y-split recession' for the Cüppers technique used previously. For the present study, we compared the results of the last 50 patients treated with the Cüppers technique with those of the first 50 patients treated with Y-split recession. Because of the retrospective design of the study, the two patient groups had to be compared in all parameters affecting strabismus. Both groups had the same age distribution (Cüppers group: mean and standard deviation 4.9 ± 2.4 years; Y-split recession group: 5.0 ± 1.4 years). Refractive errors and visual acuity (VA) showed similar distributions in both groups and could not be distinguished statistically (Cüppers group: spherical error + 2.9 ± 2.4 dioptres, astigmatic error − 0.9 ± 0.6 D, VA 0.8 ± 0.3; Y-split recession group: spherical error + 2.8 ± 3.1 D, astigmatic error − 1.1 ± 0.9 D, VA 0.7 ± 0.3).

Preoperatively, all patients used spectacles or bifocal glasses to stabilize accommodative esotropia, and VA was improved as far as possible for both eyes. However, because of the characteristics of infantile esotropia, this treatment with fully corrected or bifocal glasses or stabilization with prisms was insufficient, and surgical intervention was necessary.

Patients affected with infantile esotropia are often treated at an early age. However, in very young patients the measurement of a variable strabismus angle is difficult. Note that in this type of patients, the strabismus angle is variable, even for a fixed distance. To obtain accurate measurements of the strabismus, we included only patients who were already about 5 years old, where an accurate strabismus angle measurement was possible (Forbes & Khazaeni 2003; Koc et al. 2003; Mocan & Azar 2005; Simonsz et al. 2005; Trikalinos et al. 2005; Vasseneix et al. 2005).

All patients were tested before, 2 days and 3 months after the treatment. Patients with additional diseases were excluded from the study. The first 50 patients were treated with the Cüppers technique and the following 50 with Y-split recession. We had no complications, and no reoperation was required in any of the 100 subjects.

All patients or their legal representatives were informed of the possible side-effects of the surgical procedure before the operation and gave written consent, according to the Declaration of Helsinki.

Surgical parameters

A sketch of the two techniques is shown in Fig. 1. Their main differences are listed in Table 1.

Table 1. Comparison of surgical techniques.

	Suture location on globe	Torque reduction	Dosage parameter	Dosage variability	Globe motility	Globe retraction
Cüppers	14–15 mm behind muscle insertion	Strongly dependent on eye position	Location of suture and additional recession	3–5 suggested suture position	Reduction of adduction	In adduction
Y-split recession	3 mm behind muscle insertion	Approximately constant for all eye positions	Combination of split angle and recession	Continuous	Unchanged	None

Cüppers technique

The Cüppers technique was performed with a suture 14–15 mm behind the insertion on both medial rectus muscles (i.e. in the posterior half of the globe). Connective tissue was cut off the muscle up to the distance to the suture, and no additional recession was made. Dosage was calculated according to Cüppers (1956, 1961, 1966). We used two non-absorbable sutures, placed at the margins of each medial rectus muscle (Fig. 1A).

Y-split recession

For the Y-split recession, we chose surgical parameters such that the torque reduction was about 25%. This technique is always combined with an additional recession, in the patients presented here, by 2.6 ± 0.6 mm. Both rectus muscles were split at a length of 15 mm, and the two parts were reinserted on the globe surface with two non-absorbable sutures. The angle between the two muscle parts was 62.8 ± 5.7 degrees. First, the muscle is split bluntly along a length of 15 mm, as shown in Fig. 1B. To obtain the correct new insertion points for the two muscle halves, we employed the following procedure: a first orientation point, labelled 'A' in Fig. 1B, was located in the middle of the natural insertion of the muscle. A second point, labelled 'B', was located 6 mm straight behind A. With the compasses centred at A, the distance 'r_a' was marked on the globe with methylene blue (Fig. 1B). The same procedure was repeated from B, with the distance 'r_b'. The intersection point of the two methylene blue lines ('C') marks the new insertion point of the first muscle half. We used the following parameters: $r_a = 9.0 \pm 0.7$ mm, range 7.9–10.8 mm; $r_b = 8.0 \pm 0.7$ mm, range 6.6–10.5 mm. A detailed description of the surgical technique has been presented previously (Hoerantner et al. 2004).

Strabismus angle

The strabismus angle was tested with optimal refractive correction, by prism cover test, for near distance fixation (40 cm) and far distance fixation (600 cm). Because of the variable strabismus angle and nystagmus we also determined the strabismus angle with light reflex measurements. The strabismus angle was variable for each distance, but was largest with near fixation in all patients. For the results presented below, we used the absolute maximal and minimal value of the strabismus angle (near and far fixation).

Torque

The biomechanics of the two surgical techniques, the Cüppers technique and the Y-split recession, are quite different. Whereas the former changes the insertion point of the muscle, the latter modifies the length of the lever arm of the muscle. As a result, the torque reductions achieved by the two techniques have quite different properties. Details of a simplified mathematical model describing the underlying biomechanics have been presented previously (Haslwanter et al. 2004), as have the corresponding surgical aspects (Hoerantner et al. 2004). Figure 2 shows the expected rotating torque as a function of horizontal eye position for the two types of surgery. These curves only approximate the actual torques, as it has been shown that the existence of muscle pulleys for the rectus muscles significantly affects the oculomotor mechanics for both types of operation (Clark et al. 1999). However, as we have discussed in detail previously (Haslwanter et al. 2004), the main effect of muscle pulleys should be a horizontal shift of the curves as in Fig. 2.

The following considerations relate to a surgical change of both medial rectus muscles.

For an abduction of 6 °, the effect of the two techniques is approximately the same (Fig. 2, Eye Position − 6 °). In primary position (Fig. 2B, Eye Position 0 °), the rotating torque of a Cüppers patient is already 5% lower than in a Y-split recession. This difference clearly increases with increasing adduction (Fig. 2C).

The left margin of the grey-shaded box, labelled 'Strabismus angle' in the right half of Fig. 2, indicates the mean of the minimum strabismus angle, averaged over all patients. The right margin indicates the mean maximum strabismus angle, again averaged over all patients. It should be noted that these values constitute half the measured total strabismus angle, as both eyes are operated on.

Statistical parameters

Because of the number of patients ($n = 100$) parametric tests were used. The significance level used was $p < 0.05$. To test whether parameter changes were significant, we used the two-sided *t*-test and Levene test of variance.

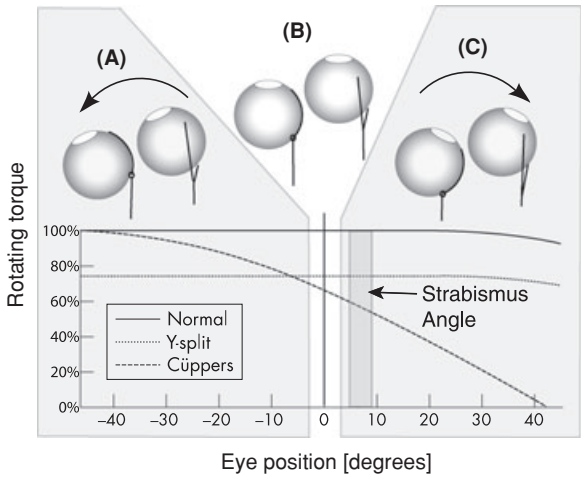

Fig. 2. Torque reduction on the medial rectus muscle. (A) Abduction area: with Cüppers the rotating torque decreases, with no effect for high abduction; with Y-split recession the torque is nearly constant. For an abduction of − 6 °, both techniques yield the same torque reduction. (B) About primary position: with Cüppers the torque further decreases, whereas it stays constant with Y-split recession. (C) Adduction area: with Cüppers the torque decreases down to zero torque for high adduction; with Y-split recession it is almost constant. The grey-shaded area labelled 'Strabismus angle' indicates the mean minimum and maximum strabismus angle, divided by 2 (left and right margin, respectively).

Results

Strabismus angle

Before the surgery, the two patient groups showed no significant difference in strabismus angle (Table 2) or angle variability. Both types of surgery significantly reduced the minimum and maximum strabismus angle ($p < 0.0001$, two-sided *t*-test). The Cüppers technique showed a significantly larger effect 2 days after the treatment than 3 months postoperatively, for minimal and maximal angle ($p < 0.0001$ two-sided *t*-test). By contrast, the effect of Y-split recession did not change significantly between 2 days and 3 months postoperatively.

The goal of our surgical corrections was to completely eliminate the strabismus angle (i.e. to obtain minimum and maximum strabismus angles that are as close as possible to zero). Figure 3 shows the minimum and maximum strabismus angles, 3 months after surgery. The maximum strabismus angle in the Y-split recession group was significantly closer to zero ($p = 0.013$, two-sided *t*-test, for the centre of the distribution) than that in the Cüppers group. The distribution in the Y-split recession patients was also significantly narrower ($p = 0.019$, Levene test of variance) than in the Cüppers patients. There was no significant difference in minimum strabismus angles between the two groups.

Because the Cüppers technique provides a higher torque reduction in adduction, we had expected that the difference between maximal and minimal strabismus angle would be lower in these patients than in patients treated with Y-split recession. However, the results showed no difference between the two patient groups.

Discussion

In pathologies with variable strabismus angles, like infantile esotropia, the treatment of oculomotor torque reduction by reducing the lever arm of the oculomotor muscles is well established and generally quite successful. Two different surgical techniques can be used: torque reduction by Cüppers technique, or torque reduction with a Y-split recession.

As we have shown previously (Haslwanter et al. 2004), the biomechanics underlying these techniques are quite different: With the Cüppers technique, the muscle is sutured to the globe on the rear half of the eyeball. Thus, the force exerted by a muscle contraction is divided into a radial force component (pulling at the suture), and a tangential force component (rotating the eye). With Y-split recession, the

Table 2. Strabismus angle distribution, all tests with optimal refractive correction. All data in degrees, with mean value and standard deviation. Two-sided paired *t*-tests were used, and all comparisons refer to the preoperative situation. Each postoperative group showed a highly significant reduction of strabismus angle compared with preoperatively. (Statistical results on comparisons between 2 days and 3 months postoperatively are given in the text.)

	Strabismus angle (degrees)					
	Preoperatively		2 days postoperatively		3 month postoperatively	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
Cüppers ($n = 50$)	16 ± 6	10 ± 5	− 4 ± 8 $p < 0.0001$	− 5 ± 7 $p < 0.0001$	5 ± 8 $p < 0.0001$	2 ± 7 $p < 0.0001$
Y-split recession ($n = 50$)	18 ± 6	11 ± 6	6 ± 5 $p < 0.0001$	3 ± 4 $p < 0.0001$	4 ± 5 $p < 0.0001$	1 ± 4 $p < 0.0001$
Cüppers ($n = 50$) angle instability	6 ± 6		2 ± 3 $p < 0.0001$		2 ± 4 $p < 0.0001$	
Y-split recession ($n = 50$) angle instability	8 ± 4		3 ± 4 $p < 0.0001$		3 ± 3 $p < 0.0001$	

SD = standard deviation.

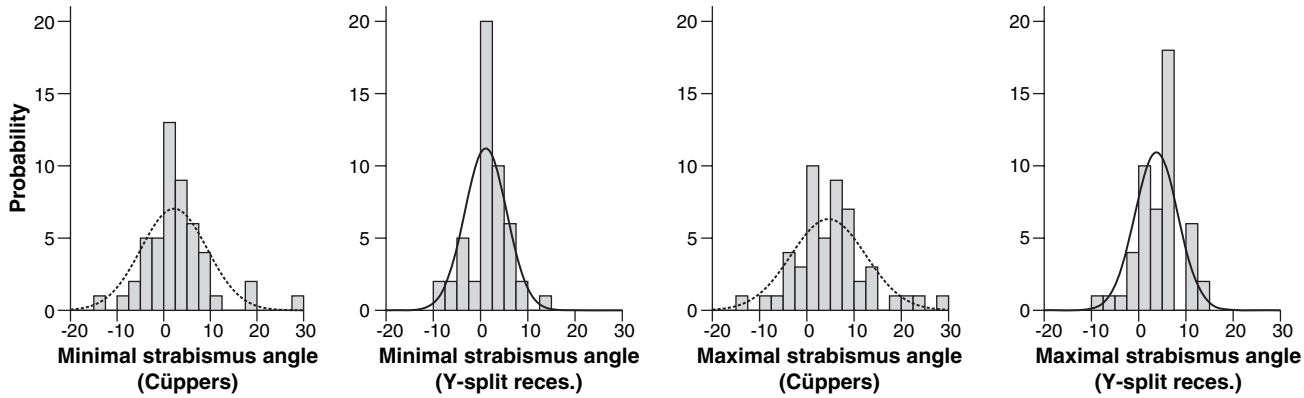

Fig. 3. Comparison of strabismus angle distribution of patients treated with the Cüppers technique (dotted lines) or with Y-split recession (solid line), 3 months after surgery.

muscle is split along 15 mm, and both ends are reattached separately, as indicated in Fig. 1. Thus the lever arm of the muscle (and thereby the rotating torque) is reduced, without any pull in the radial direction. In the Cüppers technique, the amount of torque reduction depends largely on the eye position. As Fig. 2 shows, a typical Cüppers surgery almost eliminates the muscle torque for 40 ° adduction (long dashed line, right side). This effect, which is useful in the treatment of other kinds of strabismus (Leitch et al. 1990; Clark & Demer 2002), is not exploited here. By contrast with the Cüppers technique, the torque reduction with Y-split recession is approximately constant throughout the oculomotor range (Fig. 2, short dashed line).

In a few rare cases, not related to the study presented here, patients with Y-split recessions have been reoperated a few months after Y-split recession (four patients [i.e. approximately 1% of all patients who have undergone Y-split recession]). In all these patients we inspected the split muscle and found no scar tissue between globe and muscle in any of them. In addition, the muscle was situated as it was immediately after Y-split surgery. The wound surface of the split muscle was covered by smooth, white tissue unconnected to any other structure.

However, the larger torque reduction achieved with the Cüppers technique showed no advantage in comparison with Y-split recession: the lower and constant torque reduction of Y-split recession showed equal or better results than that of the Cüppers technique. Our results indicate that, although both techniques can successfully be used for the treatment of variable strabismus angle, the Y-split recession represents a powerful alternative to the Cüppers technique. Three months after the operation, Y-split recession cases showed a significantly greater reduction in maximum strabismus angle, and a smaller interpatient distribution for this parameter. We hypothesize that these improved results may be due to the surgical advantages of this technique: the Y-split recession achieves torque reduction and recession in one operative step, which allows for greater flexibility in the choice of the surgical parameters. Whereas with the Cüppers technique an additional surgical step is necessary to achieve muscle recession, the surgical area in Y-split recession is 11 mm anterior to that in the Cüppers technique and is therefore easier to access. This provides for an improved safety margin against scleral perforation and facilitates an accurate dosage.

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