Palisade endings (PEs) are found at the musculotendinous junction in eye muscles and this is the site of much strabismus surgery. To assess the role of PEs in supplying proprioceptive information about eye position, we compared the effects of marginal myotomy and recession surgeries on tests of eye-hand coordination (open-loop pointing responses) taken before and after surgery in two groups of children having medial rectus weakening procedures for the first time. The results indicate that the myotomy is more proprioceptively "de-afferenting" than the recession, and we assume this is due to the greater disruption of PEs in this procedure. Invest Ophthalmol Vis Sci 28:1870-1872, 1987

Steinbach and Smith\(^1\) found dramatic differences in spatial localization when testing two groups of patients after strabismus surgery. Newly operated patients seemed to use a proprioceptive source to recalibrate eye position: they pointed to targets without the sight of their hands with a surprising degree of accuracy when they were tested the instant the bandage was removed from the operated eye (they had no post-operative visual experience with that eye). Patients who had multiple surgeries on the same eye muscles differed in that their pointing responses were (under the same circumstances) displaced by the amount of the eye rotation produced by the surgery. Thus, the re-operated patients seemed to lack the proprioceptive signal.

These results indicated that important proprioceptors were located around the musculotendinous junction. It was speculated by Steinbach and Smith that Golgi tendon organs (GTOs) were the important receptors. A subsequent anatomical study of the site of strabismus surgery showed that GTOs were probably not involved; rather, palisade endings (PEs) were shown to be relatively abundant at this site while GTOs were not found at all in the specimens (from strabismus surgery resection pieces and from normal donor eyes) studied.\(^2\) We have been testing additional strabismus surgery patients having recessions or marginal myotomies, to weaken the medial rectus. The recession, which is carried out where the tendon inserts into the sclera, should not involve the PEs. The myotomy procedure, however, requires the surgeon to first crush the musculotendinous region before making half-cuts from opposite sides of the muscle.\(^3\) Therefore the myotomy procedure is likely to disturb the PEs and alter any inflowing signal about changed eye position.

**Materials and Methods. Patients:** We tested 10 esotropic children undergoing unilateral surgical weakening of the medial rectus on an eye that had not had previous surgery. Their pertinent characteristics are listed in Table 1. The average age of the children having myotomies or recessions was the same for both groups, 8.4 years. Parental informed consent was obtained in all cases. The surgery was done under a general anesthetic. Pre-operatively, the children were tested the evening before, or the morning of, the surgery. Following the surgery the child's operated eye was bandaged; the patch remained in place until the time of post-operative testing (2 to 7 hr later). Vision in all cases was adequate to perform the task

**Table 1. Characteristics of subjects**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age</th>
<th>Deviation preop-far (in degrees)</th>
<th>Surgery</th>
<th>Shift* (in degrees)</th>
<th>Time of testing (hr post-op)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JM</td>
<td>11</td>
<td>7.0</td>
<td>reclLMR 4.5 mm</td>
<td>5.0</td>
<td>4.0</td>
</tr>
<tr>
<td>TS</td>
<td>9</td>
<td>12.5</td>
<td>recRMR 4.5 mm</td>
<td>−6.1</td>
<td>6.3</td>
</tr>
<tr>
<td>LH</td>
<td>9</td>
<td>17.5</td>
<td>reclLMR 4.5 mm</td>
<td>2.6</td>
<td>5.9</td>
</tr>
<tr>
<td>LM</td>
<td>7</td>
<td>7.0</td>
<td>reclLMR 5.0 mm</td>
<td>4.6</td>
<td>2.0</td>
</tr>
<tr>
<td>PS</td>
<td>6</td>
<td>10.0</td>
<td>recRMR 5.0 mm</td>
<td>−5.8</td>
<td>2.5</td>
</tr>
<tr>
<td>RV</td>
<td>15</td>
<td>12.5</td>
<td>myLMR small</td>
<td>8.3</td>
<td>2.3</td>
</tr>
<tr>
<td>AM</td>
<td>13</td>
<td>12.5</td>
<td>myLMR average</td>
<td>6.8</td>
<td>3.2</td>
</tr>
<tr>
<td>KM</td>
<td>6</td>
<td>8.0</td>
<td>myRMR small</td>
<td>−5.3</td>
<td>1.8</td>
</tr>
<tr>
<td>SP</td>
<td>4</td>
<td>5.0</td>
<td>myRMR average</td>
<td>−5.5</td>
<td>2.5</td>
</tr>
<tr>
<td>ID</td>
<td>4</td>
<td>15.0</td>
<td>myLMR average</td>
<td>6.1</td>
<td>1.7</td>
</tr>
</tbody>
</table>

* Indicates a shift to the left.

rec = recession; my = marginal myotomy; LMR = left medial rectus; RMR = right medial rectus.
without spectacle correction. Some children were mildly amblyopic but could resolve our test targets without difficulty.

**Surgical techniques:** Standard procedures for both recession and myotomies were used. In the recession, the surgeon cut the tendon as close to its insertion at the sclera as possible. For the myotomy, the distal cut was made at or very near the insertion while the proximal cut was about 4 mm away, putting it in the musculotendinous region (the medial rectus muscle has a short tendon). The cuts were made halfway through the muscle or tendon, from opposite sides.

**Apparatus and procedures:** In order to maintain a high level of interest in our test of eye-hand coordination, a computer “game” was developed, described in greater detail in Steinbach et al. The child viewed a computer generated target (a mouse or a clown with a flower or a mouse popping out of the holes in a piece of cheese) through a mirror. There was a touch-sensitive digitizing pad in the virtual image plane of the targets. Using the unseen preferred hand, the child “touched” the nose of the clown, or “pushed” the mouse back into the cheese. The digitizing pad allowed recording of fingertip position to the nearest tenth of an inch and the computer was programmed with a series of randomly-ordered speech-synthesized “messages” that proved to be very reinforcing to the children (the clown, for example, might say “Oh, that tickles!”). We were astonished at how highly motivated the children were to play this game, even after waking up from surgery with all of the usual complaints produced by general anesthetics, as well as the discomfort resulting from the surgery.

There were two target locations and six pointing responses were taken to each target, for each eye monocularly, before and after the surgery. The post-operative measures were taken the instant the bandage was removed, before that eye had any visual experience. The localization shift was calculated by subtracting the post-operative mean localization scores from the pre-operative mean localization scores.

**Results.** Table 1 shows the localization shifts for the ten patients. These results are summarized in Figure 1 and several features are apparent: (1) the amount of pre-existing deviation for the two groups is roughly equivalent (10.8° vs 10.6° for recession and myotomy groups, respectively); (2) the amount of shift found when testing the operated eye in the recession patients is less than 5°, considerably less than the presumed rotation produced by the surgery; (3) there is a large amount of shift measured using the non-operated eye of the recession patient (absolute value of 4.1°); and (4) the myotomy patient shows a larger shift when testing the operated eye (6.4°) than does the recession patient (4.8°). The myotomy patient shows a smaller shift (2.3°) than the recession patient (4.1°) when the non-operated eye is tested. Statistical analysis was done using an ANOVA; the interaction between the type of surgery and the operated and non-operated eye is significant ($F_{1,16} = 7.3; P < 0.02$).

We could not measure the amount of surgically-produced eye rotation at the time of testing. Conservative estimates were obtained 1 week post-operatively by alternate cover test and these were within 10% of the intended amount of correction, ie, they were cosmetically acceptable. Because the eye usually “settles in” to its new resting position, measures taken 2 to 7 hr after the surgery would likely indicate a greater amount of rotation than that found after 1 week.

**Discussion.** We have shown that marginal myotomy surgery produces a larger localization shift using the operated eye, and a small localization shift using the non-operated eye than the comparable measures produced by recession surgery. We believe this results from the differential availability (or fidelity) of the proprioceptive signal specifying eye position in the two groups of patients. The recession patients had the cutting and suturing of the medial rectus muscle carried out only on the tendinous portion of the muscle. There are few or no proprioceptors in the tendon exclusively. On the other hand, the musculotendinous region is the site of numerous PEs, and these almost certainly are disrupted in the myotomy procedure, either by crushing with hemostats, or by cut-
tween. We believe that the distorted or missing inflow signal about changed eye position is what led to the larger shifts measured when testing the operated eye of the myotomy patient. (These differences showed up in spite of the fact that myotomy patients had, on average, 2 more hours to recover from surgery (6.1) than did the recession patients (4.0) before their post-operative test.

Measures taken from the non-operated eye are also informative. It is known that both eyes are used in localizing targets, even when only one eye is seeing. We interpret the smaller shift found when testing the non-operated eye of our myotomized patients as reflecting lessened information about the eye position of the operated eye. If the brain is not informed about the altered location of one of the eyes (the treated one), we would expect a large shift when measuring from the operated eye and a small shift from the non-operated eye.

These results parallel those found by Steinbach and Smith. The newly operated patients in their study showed shifts measured using the non-operated eye that was larger than that found in the multiply operated patients. The shift in the new-ops was also much smaller than that found in the re-ops, when the operated eye was tested. The interpretation for both the previously reported as well as the current findings is the same: useful and accurate proprioception in the newly operated (or recession only) patients, diminished inflow in the multiply operated (or myotomized) patients.

There is a suggestion that proprioceptive signals for eye position constitute a long-term calibration mechanism, while outflow signals are read-out, over the short term. Evidence comes from the temporal course of localization changes after enucleations and from the fact that the nature of the post-operative changes, following either enucleation and strabismus surgeries, is reflected in the constant, rather than the variable errors of localization. In the data presented in this paper, the same result is found, ie, the changes in localization following the surgery (recession or myotomy) are restricted to changes in accuracy, or constant error. The variability of pointing responses, reflected in the standard deviation, is the same post-operatively as pre-operatively, for both groups of patients. The values, around 3°, are similar to those reported earlier using the same apparatus and techniques.

It would be premature to use these results to decide on preferred forms or techniques of strabismus surgery. For the patients in this study, the goal of a cosmetically acceptable result was met in both groups of patients. Some have questioned the use of the marginal myotomy as a primary procedure but we cannot say if this dispute over technique is a consequence of the different effects on the proprioceptive signal. Until more research is done, we cannot say whether a good surgical technique, in terms of the goals of strabismus surgeons and their patients, requires that proprioceptors such as the palisade ending be totally removed or left alone.

Key words: inflow, eye muscle proprioception, strabismus surgery, recession, marginal myotomy

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