SCIENTIFIC ARTICLES

Electromyography after lateral pterygoid myotomy in monkeys

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*Neuromuscular patterns of five female rhesus monkeys (*Macaca mulatta*) were studied to determine the effect of lateral pterygoid myotomy on the function of selected groups of masticatory muscles. Activity characteristics of the lateral pterygoid muscle were recorded as early as four days postoperatively. By the end of the second postoperative month, bilateral lateral pterygoid muscle activity was demonstrated in all animals. In all cases, it closely resembled preoperative patterns of lateral pterygoid muscle function. The activity was observed regardless of whether an inert barrier was used to prevent reattachment of the muscle. The results of this study indicate that the lateral pterygoid myotomy does not have a long-term effect of inhibiting the function of the lateral pterygoid muscle.*

The lateral pterygoid myotomy has been advocated for the treatment of chronic mandibular dislocation. The rationale for this procedure is based on the theory that uncoordinated activity between the lateral pterygoid muscle and the other muscles of mastication results in mandibular dislocation. If the lateral pterygoid muscle continues to contract during maximal opening, it will hold the condyle on the anterior slope of the articular eminence, causing dislocation.[1-3]

The lateral pterygoid myotomy and its modifications have the highest rate of success of the surgical treatments available for the correction of chronic mandibular dislocation reported in the literature. Boman[4,5] advocated partial lateral pterygoid myotomy with extirpation of the disk for the correction of mandibular dislocation. He reported the results of this operation in 21 patients between the ages of 13 and 55 years.[5] Fifteen cases were unilateral; six cases were bilateral. He reported no recurrences of mandibular dislocation during a follow-up period ranging from three to 12 years.

Laskin[6] modified Boman's procedure by leaving the disk intact and inserting a sheet of Silastic over the mandibular neck to prevent reattachment of the lateral pterygoid muscle. Laskin reported the results of lateral pterygoid myotomy in ten patients between the ages of 21 and 48 years. He used the bilateral procedure and noticed no recurrence of mandibular dislocation in these patients during a follow-up period of up to four years.

Well-controlled laboratory studies of lateral pterygoid myotomy procedures such as those advocated by Boman and Laskin have not been reported. Lack of recurrence of mandibular dislocation as observed clinically may be due to postsurgical scarring rather than detachment of the muscle. It is significant that there were no recurrences of mandibular dislocation after either procedure, regardless of whether an inert intermediary agent was used to prevent reattachment of the muscle. There is no indication of the function of the lateral pterygoid muscle postoperatively in either procedure. The purpose of this study was to monitor the function of the lateral pterygoid muscle and certain other masticatory muscles electromyographically to determine the extent to which the lateral pterygoid myotomy interferes with the function of the masticatory musculature. The effect of placing an inert barrier after lateral pterygoid detachment was also examined.

■ *Materials and Methods*

Five female rhesus monkeys (*Macaca mulatta*) were used. The exact birth dates of these animals were unknown. Three animals had all permanent teeth present, including fully erupted third molars. According to tooth eruption scales developed by Hurme and Van Wagenen,[7] these animals were 6 to 7 years old. One animal had all permanent teeth except for third molars and was approximately 5 to 5½ years old. One experimental animal had permanent maxillary and mandibular central and lateral incisors, as well as all permanent first molars. This animal was approximately 2 years, 8 months old.

EXPERIMENTAL GROUPS—The experimental animals were arbitrarily apportioned into the following

groups, and bilateral lateral pterygoid myotomy was done:

—two animals, bilateral lateral pterygoid myotomy alone;

—one animal, bilateral lateral pterygoid myotomy with bilateral insertion of a 0.007-in reinforced Silastic sheet along the anterior and medial surfaces of the mandibular neck to prevent reattachment;

—two animals, bilateral lateral pterygoid myotomy with unilateral insertion of a 0.007-in reinforced Silastic sheet along the anterior and medial surfaces of the mandibular neck to prevent reattachment.

The surgical procedures have been described previously.[8]

ELECTROMYOGRAPHIC TECHNIQUES—Baseline electromyographic recordings of the following masticatory muscles were obtained for all animals: bilateral anterior temporalis; bilateral anterior portion of the superficial head of the masseter; bilateral lateral pterygoid; and the suprahyoid muscle group, including the anterior digastric, mylohyoid, and geniohyoid muscles. The anterior digastric, mylohyoid, and geniohyoid muscles were regarded as a single muscle group in this experiment because of difficulty in anatomical separation during placement of electrodes.[9,10] In the rhesus monkey, the anterior heads of the digastric muscle fuse in the midline, often blending with the mylohyoid muscle.[11,12]

The methods and electromyographic techniques for performing these procedures in the rhesus monkey have been established in a number of studies in our laboratory.[9,10,13-16] Similar procedures were used in this study.

Before surgery, each animal was anesthetized by an intramuscular injection of ketamine hydrochloride (6-10 mg/kg body weight), a short-acting dissociative anesthetic that has only transient, minor effects on the neuromusculature.[17] Each monkey was placed in a primate restrainer designed for electromyography, which was placed in a soundproof, electrically shielded chamber.[13] The head of the animal was oriented in a fixed position by a Plexiglas headholder that is designed to permit normal function of the jaw (Fig 1). Bipolar platinum electrodes 8 mm in length were inserted aseptically in pairs into the following muscles at a distance of 1 to 2 mm apart: bilateral anterior temporalis, bilateral anterior portion of the superficial masseter, and the suprahyoid muscle group. Twenty-five-millimeter, Teflon-insulated bipolar needle electrodes were placed aseptically in pairs, 1 to 2 mm apart, in the lateral pterygoid muscle bilaterally, via an extraoral sigmoid notch approach. The distinction between the heads of the lateral pterygoid muscle was made according to the activity patterns obtained after insertion of the electrodes. The relationship of electrode placement to electromyographic activity pattern was examined in 12 animals in a previous study.[13] Electromyographic activity was recorded on Kodak linograph direct-print paper using a Beckman Type R Dynagraph amplifier and a Honeywell Model 1108 Visicorder.

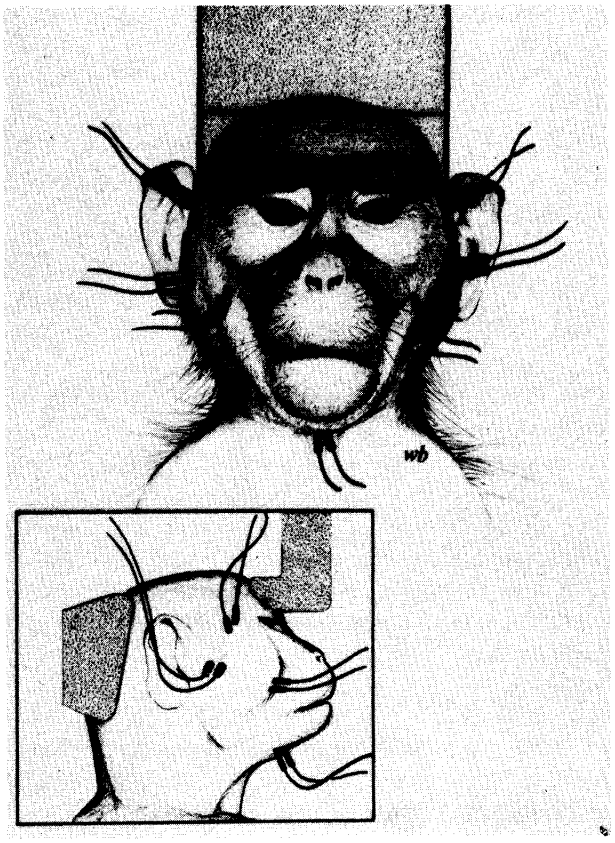

Fig 1—Animal positioned in headholder. Needle electrodes are placed bilaterally in anterior temporalis muscle, anterior border of superficial head of masseter muscle, and inferior or superior head of lateral pterygoid muscle. Set of electrodes is also placed in suprahyoid musculature at midline.

After placement of the electrodes was verified, the animals were left isolated in the soundproof room for at least 30 minutes to allow recovery from the anesthetic. After this time, postural activity, jaw reflexes, and random jaw movements were recorded while the animal remained in isolation. Later, the investigator entered the soundproof room and administered 0.5-ml increments of tap water through a syringe into the animal's mouth, generating swallows of water and subsequent clearing swallows. Each recording session lasted approximately one to 1½ hours.

ANALYSIS OF ELECTROMYOGRAPHIC DATA—The electromyographic recordings were analyzed with the aid of a five-point graduated scale of electrical activity: 0, no activity; +, minimal activity; ++, hypoactivity; +++, typical preoperative activity; ++++, hyperactivity. At the end of the control period, baseline neuromuscular patterns, including postural activity and activity during salivary and water-induced swallows, were available for each animal, together with individual ranges of variation. Each experimental animal could then serve as his own electromyographic control.

Two days postoperatively, monitoring of the animals was begun electromyographically according to the previously outlined procedures. Recordings were made at the following postoperative intervals: 2 days, 4 days, 1 week, 2 weeks, 4 weeks, and 8 weeks. These recordings provided the necessary data to compare differences in electrical activity of selected masticatory muscles resulting from lateral pterygoid myotomy.

■ *Results*

All animals tolerated the surgery well. They were fed soft foods for the first several postoperative days, until they were able to tolerate their normal diet. There were brief periods of noneating that continued for one to two days in several animals. Most animals showed mild to moderate preauricular edema and ecchymosis, which lasted from one to 1½ weeks.

CONTROL PERIOD—Baseline electromyographic records were obtained on all animals during a total of 22 recording sessions that lasted approximately one to 1½ hours each. Three to five recording sessions were held for each animal before surgery. The experimental animals had an overall pattern of bilateral mandibular function. Although individual differences were seen among animals, the patterns recorded were similar to those previously reported in the literature.

Elevator muscle group. Bilateral anterior temporalis muscle activity was observed during the maintenance of the mandibular postural position and during certain water- and salivary-stimulated swallows (Fig 2,3). Intermittent, often well-circumscribed bursts of activity were recorded from the superficial portion of the masseter muscle bilaterally in association with postural maintenance and during certain swallows. Both muscles were active during the closing phase of the chewing cycle.

Suprahyoid muscle group. Intermittent tonic discharges were observed during mandibular postural maintenance (Fig 2). Well-circumscribed bursts of activity were recorded during water-, salivary-, and masticatory-stimulated swallows in all instances (Fig 3).

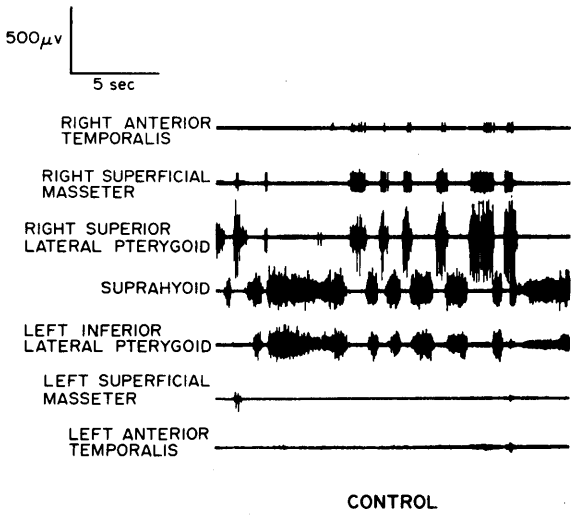

Fig 2—Overview of typical electromyographic activity of muscles studied. Note antagonistic activity of right superior head and left inferior head of lateral pterygoid muscle. Inferior head of this muscle acts with suprahyoid muscle group in mandibular opening. Superior head acts with elevator musculature in mandibular closing. Note also that animal is biting unilaterally (recording speed, 10 mm/sec).

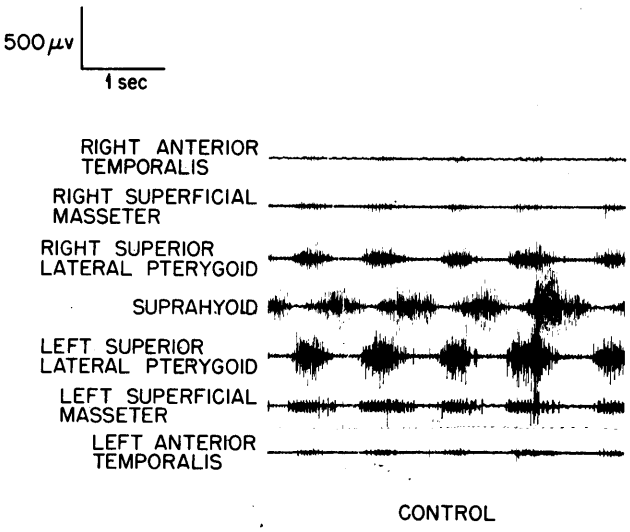

Fig 3—Electromyographic recording of mastication and deglutition. Swallow is indicated by well-circumscribed burst of suprahyoid activity, preceded by concomitant activity in elevator musculature and in superior head of lateral pterygoid muscle (recording speed, 50 mm/sec).

Lateral pterygoid muscle. Little postural activity was observed in either head of this muscle. The inferior head appeared to function with the suprahyoid muscle group in wide-opening movements only (Fig

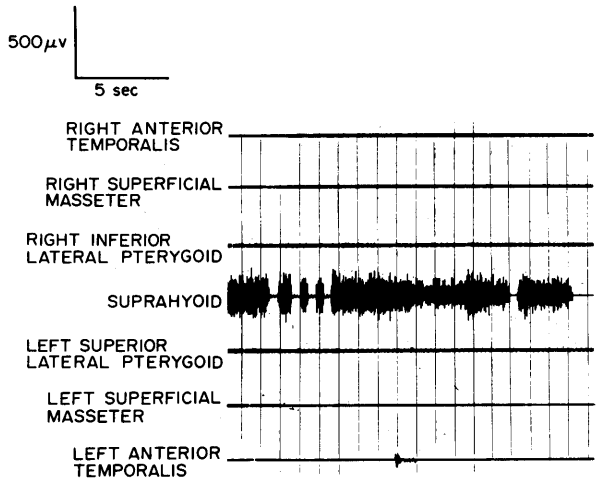

Fig 4—Electromyographic recording taken on second day after bilateral lateral pterygoid myotomy (no Silastic implant). Note hyperactivity of suprahyoid musculature and elimination of lateral pterygoid muscle firings. This lack of activity indicated that lateral pterygoid function was interrupted by surgical intervention (recording speed, 10 mm/sec).

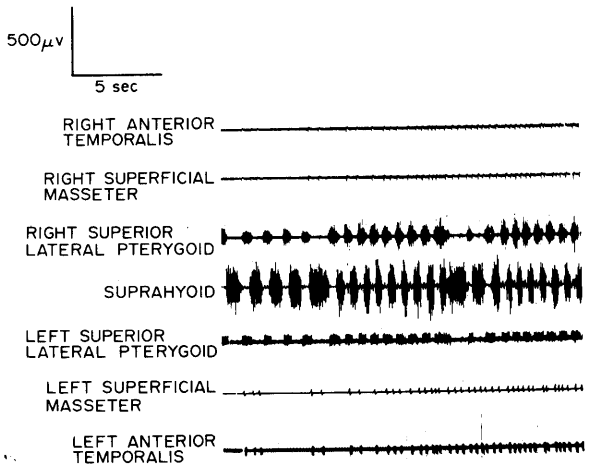

Fig 5—Electromyographic recording taken four days after bilateral lateral pterygoid myotomy and unilateral (right side) Silastic implant. Animal showed earliest return of function in lateral pterygoid musculature of five experimental animals. Note bilateral activity from superior head of lateral pterygoid muscle (recording speed, 10 mm/sec).

2). The superior head functioned along with the elevator musculature in mandibular closing movements, their activity occurring concomitantly. The inferior head of the lateral pterygoid muscle did not function during swallowing; however, the superior head was active in all swallows (Fig. 3).

TWO DAYS POSTOPERATIVELY—*Elevator muscle group.* Tonic discharges were observed from the anterior temporalis muscle bilaterally during mandibular postural maintenance; the intensity of these discharges varied among animals. In most animals, the discharges were mild to moderate, whereas in one animal, they were weak to minimal. Activity recorded from the superficial portion of the masseter muscle varied between animals and between sides; recorded activity varied from tonic discharges to discrete bursts of activity. Masseter muscle activity did not occur in two animals. Mild activity occurred on the left side but not on the right side in one animal. During deglutition, mild activity of the anterior temporalis muscle was recorded. Minimal activity was seen in the left superficial portion of the masseter muscle, whereas mild activity was seen in the right masseter muscle.

Suprahyoid muscle group. Strong activity was observed in this group in all animals (Fig 4). Well-circumscribed bursts of activity, as well as discrete discharges, were observed. There were fewer silent periods in comparison with preoperative control levels. Well-circumscribed bursts of activity were also seen in association with water- and salivary-stimulated swallows, bursts that were similar to those observed during the control period.

Lateral pterygoid muscle. Activity from either the superior or inferior heads of this muscle was eliminated in most animals after surgery, both during postural maintenance and during deglutition (Fig 4); however, activity of the inferior head occurred in one animal in association with wide opening, whereas activity of the superior head during swallowing occurred in another animal.

FOUR DAYS POSTOPERATIVELY—*Elevator muscle group.* Some activity of the bilateral anterior temporalis muscle, in association with mandibular postural maintenance, occurred in all animals (Fig 5). Intensity of discharge varied among animals. Activity recorded from the superficial portion of the masseter muscle also varied among animals and between sides; however, at least minimal activity of the masseter muscle occurred in all animals. Elevator muscle activity associated with deglutition occurred in only one experimental animal.

Suprahyoid muscle group. Strong suprahyoid activity continued in three animals. Although well-circumscribed bursts of activity, as well as tonic discharges, were observed, there were fewer silent periods in comparison with preoperative controls. Well-circumscribed bursts of activity were seen in association with both water- and salivary-stimulated swallows.

Lateral pterygoid muscle. Increased activity was seen in certain animals in association with postural main-

tenance. In wide opening, activity in the inferior head was seen bilaterally in one animal and activity in the inferior head was seen unilaterally in two animals. As in the control period, the inferior head did not function during swallowing. Activity in the superior head of the lateral pterygoid muscle was observed bilaterally in one animal and unilaterally in three animals (Fig 5).

ONE WEEK POSTOPERATIVELY—*Elevator muscle group.* Mandibular postural activity was seen bilaterally in the anterior temporalis muscles. Recorded activity varied from tonic discharges to discrete bursts of activity. More uniform activity was seen in the superficial portion of the masseter muscle in which both tonic discharges and discrete bursts of activity were observed. Elevator muscle activity, in association with deglutition, occurred in only one animal.

Suprahyoid muscle group. Strong activity from this muscle group was observed in four animals. Well-circumscribed bursts of activity, as well as tonic discharges, were seen with interspersed periods of relative inactivity. Well-circumscribed bursts of activity were seen in association with both water- and salivary-stimulated swallows.

Lateral pterygoid muscle. Activity in the inferior head was seen bilaterally in two animals only in association with wide mandibular opening, whereas one animal had unilateral return of inferior head function. The inferior head of the lateral pterygoid muscle did not function during deglutition a week postoperatively. However, a return of superior head function was observed bilaterally in two animals and unilaterally in three animals.

TWO WEEKS POSTOPERATIVELY—*Elevator muscle group.* Mild to moderate bilateral activity from the anterior portion of the temporalis muscle occurred in all animals during mandibular postural maintenance. Bilateral activity also occurred in all animals in the superficial portion of the masseter muscle. The elevator musculature of three of the five animals was active during water- and salivary-stimulated swallows.

Suprahyoid muscle group. Strong activity was again observed in four animals, with fewer silent periods in these animals compared with preoperative control levels. Patterns of activity during deglutition were comparable with those observed during the control period. Activity in the inferior head was seen in all animals only in association with wide mandibular opening. Mild to moderate activity in the superior head was observed bilaterally in association with swallowing in two animals; similar activity was seen unilaterally in three other animals.

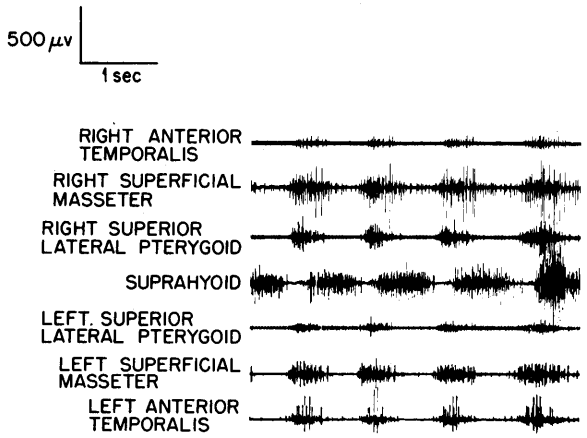

Fig 6—Electromyographic recording taken eight weeks after bilateral lateral pterygoid myotomy and unilateral Silastic implant. Superior head of right lateral pterygoid shows activity in conjunction with elevator musculature. Minimal activity of superior head is shown on left side (recording speed, 50 mm/sec).

Lateral pterygoid muscle. Bilateral inferior head activity was seen in four animals in association with wide mandibular opening only, whereas unilateral activity was observed in the other animal. Mild to moderate activity in the superior head occurred bilaterally in association with swallowing in two animals, whereas unilateral activity was observed in the other animals.

FOUR AND EIGHT WEEKS POSTOPERATIVELY—*Elevator muscle group.* All animals had activity in this muscle group during postural maintenance, which corresponded closely with that seen preoperatively. In four animals, elevator muscle activity occurred in association with water- and salivary-stimulated swallows by four weeks, and by eight weeks, this activity was similar to preoperative control levels in all animals (Fig 6,7).

Suprahyoid muscle group. Suprahyoid muscle group activity that corresponded closely with preoperative control levels occurred in all animals.

Lateral pterygoid muscle. Activity that corresponded closely with preoperative control levels occurred bilaterally in all animals. The inferior head of the lateral pterygoid muscle appeared to function with the suprahyoid muscle group in wide opening mandibular movement. The superior head functioned with the elevator musculature in mandibular closing movements, the activity appearing concomitantly (Fig 6). As we observed during the control period, the inferior head did not seem to function during swallowing (Fig 7). Bilateral activity in the superior head occurred in association with swallowing in all animals.

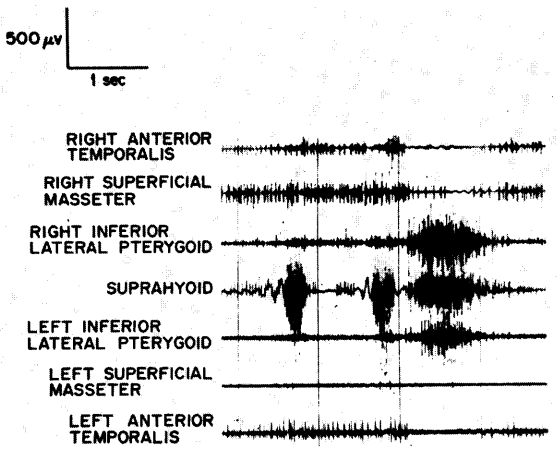

Fig 7—Electromyographic recording made eight weeks after bilateral lateral pterygoid myotomy without Silastic implants. Note participation of both inferior heads of lateral pterygoid muscles in mandibular opening. No activity of inferior heads is observed during salivary-stimulated swallows (recording speed, 10 mm/sec).

■ *Discussion*

This study showed electromyographically that the lateral pterygoid myotomy has only a transient effect on this muscle. Although myotomy usually resulted in an initial cessation of all functional activity, a gradual return of this activity was observed. By the eighth postoperative week, electromyographic activity in all animals corresponded closely to that observed during the preoperative control period.

This study also investigated the use of a tissue-tolerated inert agent (Silastic) in preventing muscle reattachment. The electromyographic recordings from those animals in which a Silastic barrier was used could not be distinguished from recordings from those animals in which it was not used. The use of an inert barrier did not seem to affect substantially the reattachment of the lateral pterygoid muscle after myotomy.

The results of this study can also be used to further define the role of the lateral pterygoid muscle in mandibular movement in the monkey. McNamara[9,10] has hypothesized that the two heads of the lateral pterygoid muscle are functionally distinct. He suggests that the inferior head acts with the suprahyoid muscle group in jaw opening and in lateral and anterior movements. In contrast, the superior head is active both in closing movements (mastication) and in movements such as swallowing, which are characterized by little or no elevator activity.[16] In this study, both heads of the lateral pterygoid muscle were detached from their insertion at the mandibular condyle. No muscle activity usually was discernible immediately after surgery, indicating that the subsequent electrical activity that was monitored electromyographically probably originated from the lateral pterygoid muscle and not from adjacent muscles.

This study confirms that there are two functionally, as well as anatomically, distinct heads of the lateral pterygoid muscle in the monkey. The inferior head functions with the suprahyoid muscle group in wide mandibular opening but does not appear to function during swallowing. The superior head acts with the suprahyoid muscle group during swallowing to produce a well-circumscribed burst of electrical activity characteristic of the swallow. Although not described in detail in this study, three patterns of electromyographic activity were observed during the swallow that corresponded with those previously reported by McNamara and Moyers.[16]

Some alterations of neuromuscular function were observed in other muscles of mastication after surgery. For example, the anterior portion of the temporalis muscle showed mandibular postural activity in all of the animals, beginning with the first postoperative recording session. The superficial portion of the masseter muscle also demonstrated mandibular postural activity as early as the second postoperative day. However, this activity did not return in all cases until the fourth postoperative day. The masseteric nerve may have been transiently injured during the surgical approach to the lateral pterygoid muscle via the sigmoid notch, inducing neurapraxia. Severance of this motor nerve would preclude a rapid return of activity during the first postoperative week.

After lateral pterygoid myotomy, the suprahyoid muscle group becomes hyperactive in all animals. Although tonic discharges and well-circumscribed bursts of activity were observed, there were fewer periods of inactivity in comparison with preoperative controls. This may represent a neuromuscular compensation for an anterior and inferior displacement of the mandibular condyle that results from edema and pain in the temporomandibular joint occurring as a result of the surgical procedure. By the end of the first postoperative month, the activity of this muscle group had returned to preoperative control levels. This corresponded to the return of elevator muscle activity associated with deglutition.

As in all experimental studies, a note of caution should be made regarding the interpretation of these findings. First, an animal model was used in this study of lateral pterygoid myotomy. There are certain gross morphological differences between the configuration of the temporomandibular joints of man and rhesus monkey.[18,19] Although, of the most commonly used

laboratory species, the temporomandibular joint in the rhesus monkey is the closest to that of man, direct comparisons between the findings in the monkey and the clinical situations encountered in human patients should be made with caution. Also, the experimental model used in this study was not analogous to the human patient with dislocation as the animals used were presumably normal. However, because of the many similarities between man and monkey, electromyographic data from this study may enable certain conclusions to be drawn concerning this procedure. According to the clinical criterion of lack of recurrence of mandibular dislocation, the lateral pterygoid myotomy must be considered a successful procedure. However, this study has shown that the surgical intervention has only a transient impact on the function of the lateral pterygoid muscle, at least as observed electromyographically. As it does not appear that the lateral pterygoid myotomy eliminates lateral pterygoid muscle function, other mechanisms that limit joint mobility (for example, postsurgical scarring) may be operative. Thus, the elimination of chronic mandibular dislocation might be accomplished more easily by surgical procedures directed solely at induction of these mechanisms.

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