A Physiometric Analysis of Lip Function in Cleft and Noncleft Subjects

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The role of the lips as a primary articulatory mechanism in speech has been suggested by a number of authors (*1, 2, 4*). Whether the lips possess adaptive ability to compensate for anatomical aberrations or associated articulatory deficiencies is still a matter of conjecture. Children born with clefts of the lip have a congenital disruption in the continuity of their perioral musculature. This, of course, is and should be surgically repaired. While there are many different surgical techniques used to repair cleft defects, the goals of these procedures are the same—good cosmesis coupled with adequate functional mobility of the upper lip. In order for these goals to be reached, much care and precision are necessary during the surgical repair procedures. With this in mind, the question then arises about the effects, if any, that the presence of a cleft coupled with its surgical repair has on functional lip movement. In an attempt to resolve this question, this study was undertaken to determine whether there are differences in lip function between cleft and noncleft subjects during speech.

Method

The technique of physiometric cinematography, as described by Rosenblum (*3*), was the investigative method employed in this study. This technique involves the use of standardized gridlines projected (from oriented slide projectors) onto the soft tissue of the face, enabling the investigator to position each subject's head anatomically at a constant distance from a motion picture camera. Profile motion pictures were then taken of each subject at the rate of 20 frames per second. Each subject was instructed to speak in a normal conversational manner into a microphone which was positioned six inches from his mouth. The intensity

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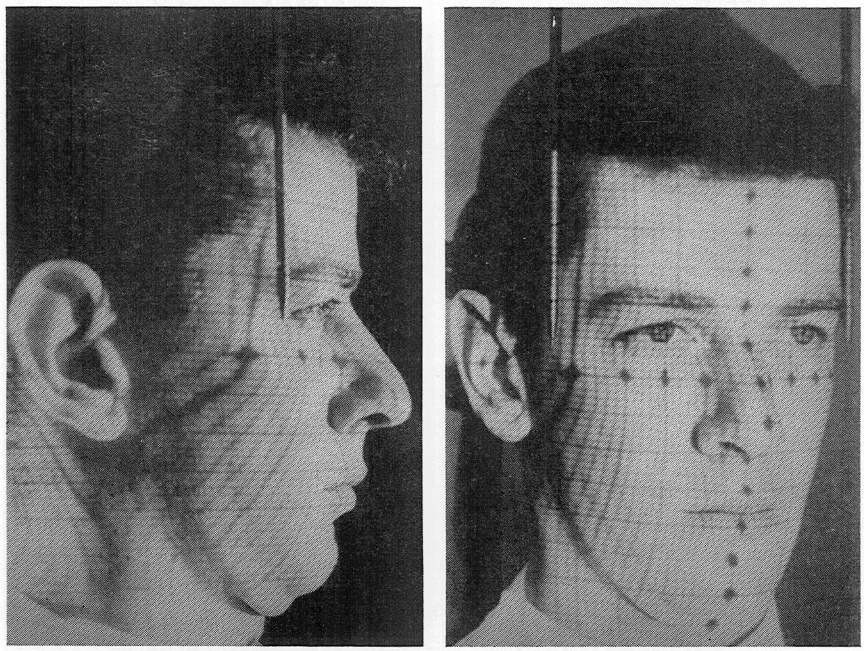

FIGURE 1. Profile and frontal view of a subject anatomically aligned for filming procedures.

level of individual speech samples was thus monitored and was not found to vary more than 10% of the range shown on the tape recorder imput dial.

The accentuated vertical and horizontal gridlines projected from the oriented slide projectors and the vertical metal rods suspended from a midline bar fixed above each subject were used, along with facial soft tissue points, to position each subject's head during filming procedures (Figure 1). The soft tissue points utilized were: Orbitale, the lower-most point on the bony edge of each orbit; Nasion, the point of junction of the frontal and nasal bones; and Laterale, the most distal point on the lateral surface of each orbit. The point Nasion on each subject's face was aligned to coincide with the accentuated vertical gridline. The landmark Laterale on each side was aligned in the same horizontal plane with the tip of each vertical midline rod. Orbitale and the superior edge of the external auditory meatus were positioned to lie along the first fine gridline above the accentuated horizontal gridline. The plane which runs through these two points is known as the Frankfort Horizontal Plane.

The anatomical points used in analyzing lip function in this study were the most anterior-inferior point of the vermilion of the upper lip (point A1) and the most convex point on the anterior surface of the vermilion of the lower lip (point LC). The vertical change in lip position was measured in millimeters along the two lines which connected the

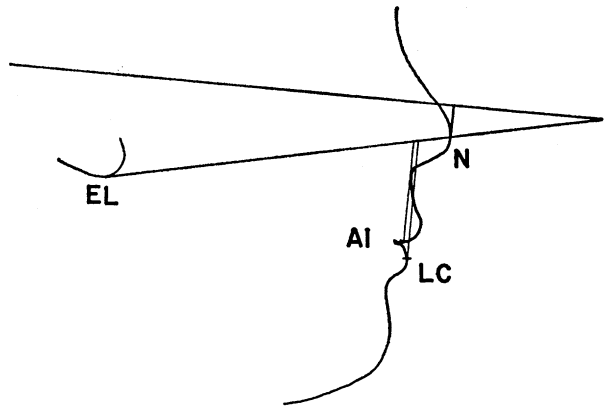

FIGURE 2. Landmarks used for tracing.

points A1 and LC to EL-N, the ear lobe to nose line. The amount of anterior (or posterior) change in lip position was measured in millimeters from the most convex point of the nose to the points of intersection of the two lines connecting A1 and LC with EL-N. These changes were recorded for each individual from tracing (Figure 2).

It was originally thought that perpendiculars dropped from the Frankfort Horizontal Plane to the desired anatomical points on the lips could be used in the measurement of lip movement. However, this would not take into account the effect of head movement during phonation of the experimental phrase. By using the line EL-N as a base and utilizing the complement of the angle FH-N-EL to project lines to the anatomical points on the lips, the effect of head movement was negated since the points EL and N moved with positional head changes during function.

Subjects

The sample utilized in this study included 23 cleft lip and palate subjects and seven noncleft subjects. Of the cleft subjects, seven had bilateral clefts of the lip and palate, eight had unilateral clefts of the lip and palate, and eight had unilateral clefts of the lip only with no involvement of the hard and soft palates. The age range of the cleft subjects was between five years, two months, and 12 years, six months. Fourteen of the cleft subjects were male and nine were female. The cleft defects had all been surgically repaired and no surgical procedures had been attempted on any cleft subjects during the 12-month period immediately preceding the filming procedure.

Seven noncleft subjects were used as a control sample. The age range of the control sample was from five years, three months to 13 years of age. These subjects had experienced no surgical procedures involving the face and had no speech impairment.

The experimental and control subjects were of average or above average intelligence and none had experienced any debilitating hearing loss.

Discretion was exercised in picking the cleft subjects to be studied in this analysis. This was done to prevent biased conclusions regarding lip mobility as a result of including individuals whose history revealed an excessive number of surgical procedures.

Analysis

Patterns of lip function were plotted and graphed in a frame-by-frame analysis during the phonation of the plosive phrase *Bobby is a big boy.* To facilitate analysis, the extent of movements was analyzed statistically between the initial and secondary bilabial plosives. This peak activity of lip function, occurring during the phonation of the *ah* sound of the first syllable in *Bobby,* was thought to be a valid test of lip mobility during bilabial plosive articulation. Changes in position of the lips during function were analyzed statistically during peak movement to determine whether or not significant differences existed in lip function between the cleft and noncleft subjects. This analysis consisted of comparing the means at the 5% level of significance using a t test. An analysis of variance (F test) was used to compare the means of the individual cleft groups. This was done at the 5% level of significance to determine whether significant differences existed between the means of the individual cleft groups.

Results

Anterior-Posterior Movement of the Upper Lip (A1-N). The analysis of the movement of the upper lip in an anterior-posterior direction during bilabial plosive activity revealed a relatively limited magnitude of upper lip movement in this plane. This movement was defined by the change in the anterior-posterior relationship of the most anterior-inferior point of the vermilion of the upper lip (point A1), to the most convex point of the nose (point N).

The very small range of anterior-posterior movement of the upper lip, which was from three to four millimeters, was characteristic of both the cleft and the noncleft sample. Since the upper lip was so limited in anterior-posterior movement during this function, it was not possible to ascertain whether a surgically repaired cleft lip exhibited an impairment in functional anterior-posterior movement.

Anterior-Posterior Movement of the Lower Lip (LC-N). The movement of the lower lip in an anterior-posterior direction during bilabial plosive function was found to be of a greater magnitude than the corresponding movement of the upper lip. This range in movement was from one to nine millimeters during peak magnitude of anterior-posterior movement of the lower lip. This was observed during phonation of the initial syllable of the experimental phrase shown on Table 1. None of the between group differences were significant.

Vertical Opening Between the Lips (A1-LC). The amount of ver-

TABLE 1. Anterior-posterior movement of lower lip, in mm, for 3 cleft subgroups, total cleft group, and control group. None of between-cleft group differences were significant; the difference between total cleft group and control group was also not significant.

Unilateral Lip and Palate		*Bilateral Lip and Palate*		*Unilateral Lip Only*		*Control Group*	
Frame No.	*Distance*	*Frame No.*	*Distance*	*Frame No.*	*Distance*	*Frame No.*	*Distance*
6	3	6	4	5	7.5	4	3.5
4	2	5	1	5	4	7	4.5
7	2.5	6	5	6	4.5	5	3.5
7	1.5	6	5.5	6	2	7	6
4	4	5	4	7	3	4	7
4	2	3	1	6	5.5	6	6
6	5.5	5	9	5	5	4	2.5
4	3			2.5			
4–7	1.5–5.5	3–6	1–9	5–7	2–7.5	4–7	2.5–7
Mean 2.93 mm		Mean 4.21 mm		Mean 4.25 mm			
Mean, Total Cleft Group 4.00 mm						Mean, Control Group 4.71 mm	

tical opening between the upper and lower lips during bilabial plosive articulation was also analyzed. This opening was defined as the vertical dimension between the most anterior-inferior point of the vermilion of the upper lip (point A1) and the most convex point of the anterior vermilion of the lower lip (point LC). The distance between these two points was measured in millimeters during maximal opening which occurred during the articulation of the first syllable of the sentence.

All the cleft subjects were combined into a group and the mean value of the maximal vertical opening between the lips for that group was compared with the value with the control group. A statistically greater dimension of lip aperture was to be found for the cleft sample. The mean maximal vertical opening between the lips of the cleft sample was 13.06 mm, while the same mean measurement was found to be 9.92 mm for noncleft sample (Table 2). The peak mean value of the vertical opening between the lips was determined for each of the three cleft groups and these were individually compared to the noncleft mean. The results showed that only the unilateral clefts of the lip and palate were statistically different from the noncleft group in this dimension.

VERTICAL MOVEMENT OF THE UPPER LIP (A1-EL-N). With a difference in peak vertical opening of the lips established between the cleft and noncleft sample, the question then arises as to whether this difference can be attributed to the vertical movement of either the upper or lower

TABLE 2. Maximal vertical opening between lips, in mm, for 3 cleft subgroups, total cleft group, and control group. Significant differences were obtained between the total cleft group and noncleft group and between the unilateral lip and palate group and noncleft group.

Unilateral Lip and Palate		*Bilateral Lip and Palate*		*Unilateral Lip Only*		*Control Group*	
Frame No.	*Distance*	*Frame No.*	*Distance*	*Frame No.*	*Distance*	*Frame No.*	*Distance*
6	11	8	8.5	6	17	3	9
7	17	4	11	4	9	7	9
6	12	7	9.5	6	12	6	8.5
7	12	7	19.5	7	14	6	12
5	12.5	5	12	9	13	4	15.5
4	12.5	6	8.5	6	14	6	9.5
5	13	5	18	4	12.5	5	6
5	17			5	15		
4–7	11–17	4–8	8.5–19.5	4–9	9–17	3–6	9–15.5
Mean 13.37 mm Significant at 5%		Mean 12.42 mm Not Significant at 5%		Mean 13.31 mm Not Significant at 5%			
Mean, Total Cleft Group 13.06 mm						Mean, Control Group 9.92 mm	

lip or both. Vertical movement of the upper lip was defined as the change in vertical dimension between the most anterior-inferior point of the vermilion of the upper lip and the line which connects the most inferior point of the ear lobe with the most convex point of the nose. A reduction in this dimension would indicate that the upper lip moved away from the lower lip and closer to the baseline, EL-N. Frame-by-frame analysis of the vertical movement of the upper lip revealed little movement (two or three millimeters) during bilabial plosive articulation. This was true for both the cleft and noncleft subjects. Thus, the upper lip exhibits a rather small magnitude of movement in a vertical as well as an anterior-posterior direction during bilabial plosive articulation.

VERTICAL MOVEMENT OF THE LOWER LIP (LC-EL-N). The vertical movement of the lower lip was defined as the change in vertical dimension between the most convex point of the vermilion of the lower lip, to the ear lobe to nose line. A reduction in this dimension during function would indicate that the lower lip was moving closer to the baseline, EL-N and an increase in this dimension would indicate the lower lip was moving further away from the baseline.

There was a statistically greater dimension of lower lip movement for the total cleft group when compared to the noncleft group sample. That

TABLE 3. Maximal vertical lower lip movement, in mm, for 3 cleft subgroups, total cleft group, and control group. Significant differences were obtained between the total cleft group and noncleft group and between the noncleft group and the unilateral lip and palate and the bilateral lip and palate subgroups.

Unilateral Lip and Palate		*Bilateral Lip and Palate*		*Unilateral Lip Only*		*Control Group*	
Frame No.	*Distance*	*Frame No.*	*Distance*	*Frame No.*	*Distance*	*Frame No.*	*Distance*
5	8	5	8	4	11	4	9
5	11.5	5	14	5	5	5	5
5	12.5	6	9	6	13	5	6
7	11	6	16	6	13	6	9
7	11	6	18	7	11	6	10
7	14	6	15	7	13	6	10
7	14	7	11.5	8	12.5	7	12
8	20			9	13		
5–8	8–20	5–7	8–18	4–9	5–13	4–7	5–12
Mean 12.62 mm Significant at 5%		Mean 13.07 mm Significant at 5%		Mean 11.43 mm Not Significant at 5%			
Mean, Total Cleft Group 12.54 mm						Mean, Control Group 8.71 mm	

is, the lower lip moved further away from the baseline in the cleft sample. Thus, it would seem that the lower lip contributes greatly to the greater dimension of the lip aperture exhibited by the cleft subjects during maximal function in bilabial plosive articulation. The mean value of maximal vertical lower lip movement was 12.54 mm in the cleft sample and 8.71 mm in the noncleft sample (Table 3).

The mean value of maximal vertical lower lip movement was then determined for each of the three cleft groups and these were individually compared to the noncleft mean. The results reveal that the unilateral and bilateral lip and cleft palate groups of lip and palate show a significantly greater maximal vertical lower lip movement during bilabial plosive articulation than did the lip only cleft group. Whether this is due to increased mandibular movement or to increased movement of the lower lip per se could not be determined by the methods used in this study.

Analysis of Variance. The F test was utilized as a method to analyze the variance, if any, which existed between the means of the cleft groups when they were separated according to anatomical classification. This was done to determine if any one cleft group differed significantly from the other cleft groups by virtue of its anatomical classification. The re-

sults revealed that no significant differences existed among cleft group means in either the amount of opening between the lips or the amount of vertical lower lip movement. (These were the only categories in which the mean of cleft sample, when taken as a whole, differed significantly from the noncleft mean.)

CONSISTENCY IN FUNCTIONAL LIP PATTERN. The functional lip patterns which occurred seemed to be somewhat consistent within a given individual. This consistency was not to be found in the magnitude of the movements exhibited, but rather in the similarity of graphic representation of these movements.

This conclusion was based on repeated observations of the same subject during plosive articulation and on group-to-group comparisons of functional lip patterns. This suggests that although there is a difference in magnitude of dimension in lip function existing between cleft and noncleft subjects, all these subjects seem to move their lips in similar directions in trying to attain the same results in bilabial plosive articulation.

The subjective analysis of variation in the magnitude of lip movement revealed that the cleft subjects, particularly the bilateral cleft group, exhibited a wider range in variation of peak functional movements. This observation would suggest that if articulatory variations are present, they are more likely to be observed among cleft subjects, particularly those possessing the greatest degree of original cleft involvement. This variation again was not found in the pattern of movement but in the magnitude of movement.

Discussion

The findings recorded in this study revealed no direct evidence to support the contention that upper lip function is appreciably impaired, at least during the bilabial plosive articulation, either by the presence of a cleft lip or a surgical repair of a cleft lip. It should be remembered, however, that the extent of activity required of the upper lip during the articulation of the experimental plosive phrase was relatively small. This was true not only of the cleft sample but of the noncleft sample as well.

The observation that vertical lower lip movement was significantly greater in cleft subjects during bilabial plosive activity that in noncleft subjects would suggest that differences in lip activity which occur between cleft and noncleft subjects during plosive articulation are not directly related to the site of the cleft anomaly. Thus, these differences might be classified as compensatory in nature. That is, the lower lip and/or mandibular movement might be compensating for the presence of the cleft anomaly and/or its subsequent surgical repair during bilabial plosive articulation.

Summary and Conclusions

A standardized oriented cinematographic method was used in a study of lip movement during bilabial plosive activity. The results of this study lead to the following conclusions: There is no difference in magnitude of anterior-posterior movement of the upper lip or anterior-posterior movement of the lower lip between cleft and noncleft subjects during bilabial plosive articulation. There was also no difference in the magnitude of the vertical movement of the upper lip between cleft and noncleft subjects during bilabial plosive articulation.

There is a significantly greater magnitude of vertical opening between the lips exhibited during maximal bilabial plosive function in the cleft sample when taken as a whole. There is a significantly greater magnitude of vertical lower lip movement exhibited during maximal plosive function in the cleft sample when taken as a whole.

In this study of lip function it appears that functional lip movements during bilabial plosive activity are not directly related to the type of cleft defect, but are more related to the presence of a cleft. This was exemplified by the significant differences noted in the magnitude of vertical opening between the lips and the vertical movement of the lower lip. These differences were observed when the cleft sample as a whole was compared to the noncleft sample.

A subjective analysis of the overall pattern of lip function revealed a consistency of functional lip movements during bilabial plosive articulation. This consistency of pattern was present within individual subjects and pertains more to the type of movements rather than to the exact magnitude of the movements.

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