Quantifying Labial Strength and Function in Facial Paralysis  
Effect of Targeted Lip Injection Augmentation

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IMPORTANCE  Facial muscle weakness from paralysis or muscle dystrophy can significantly affect lip strength and function. Lip muscle weakness may result in articulation difficulties and spillage of food, both of which are socially and functionally disruptive for patients. There are few quantitative data on the effect of facial paralysis on lip strength.

OBJECTIVES  To quantify the effect of facial paralysis and muscular dystrophy on lip strength and evaluate the effectiveness of targeted lip injection augmentation.

DESIGN, SETTING, AND PARTICIPANTS  Analysis of patients at the Johns Hopkins Hospital between January 1, 2008, and July 31, 2014, presenting for treatment of lip incompetence due to facial paralysis and facial muscular dystrophy was prospectively undertaken. Patients who had undergone direct surgical lip procedures were excluded.

MAIN OUTCOMES AND MEASURES  Lip pressure measurements, anterior bolus spillage, and articulation of bilabial sounds before and after treatment were assessed by a single speech pathologist. Lip pressures were measured with the Iowa Oral Performance Instrument.

RESULTS  Twenty-two patients with unilateral facial paralysis were evaluated for this study. Three patients with facioscapulohumeral muscular dystrophy were also evaluated. In unilateral facial paralysis, central lip strength was reduced in all patients compared with sex-corrected normative data (mean [SD] central lip strength, 5.5 [2.5] kPa in females and 9.6 [4.6] kPa in males). Compared with the nonparalyzed side, labial strength on the paralyzed side was reduced by 69%. After injection augmentation of the paralyzed side, labial strength improved across the entire lip. Mean lip strength improved by 0.7-fold in the central lip from 5.60 to 9.30 kPa (P = .009), by 1.4-fold on the paralyzed side from 2.2 to 5.33 kPa (P = .006), and by 0.4-fold on the unaffected side from 7.11 to 9.56 kPa (P = .12). Lip strength in the 3 patients with facioscapulohumeral muscular dystrophy were uniformly reduced across the entire lip and improved by 6- to 7-fold after injection augmentation. All patients were noted by the speech pathologist to have improved articulation of plosive sounds and decreased anterior bolus spillage after the injection.

CONCLUSIONS AND RELEVANCE  Labial strength is reduced across the lip in patients with unilateral facial paralysis. The Iowa Oral Performance Instrument is an effective tool for measuring labial strength and can be used to evaluate the effectiveness of facial reanimation procedures. Injection augmentation of the lip is a simple and effective means of improving labial strength, bilabial sounds, and anterior spillage in patients with facial paralysis or facial muscular dystrophy.

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The lip is an important aesthetic feature of the face and functionally important in speech and swallowing. The orbicularis oris and extrinsic perioral muscles maintain the form, tone, and movement of the lips. The orbicularis oris muscle works together with the superior pharyngeal constrictors and buccinators to generate positive pressure during the oral phase of swallowing. Adequate interlabial pressure is necessary to prevent anterior bolus spillage and drooling. To generate the bilabial plosive sounds /p/ and /b/, airflow from the lungs is interrupted by complete lip closure. Production of the consonants /f/ and /v/ require lower lip tension for controlled, precise airflow.1 Facial paralysis that affects the lip musculature can significantly affect swallowing, articulation, and lip sufficiency. Patients with facial paralysis often avoid eating in public because of anterior bolus spillage. They also have difficulties in generating bilabial consonants. In reversible paralysis where the facial muscles are physiologically intact, reinnervation of the orbicularis oris and other extrinsic lip muscles provide the best chance for restoring tone and oral competence. In irreversible paralysis and conditions of muscular dystrophy, static slings and wedge resections have been used to improve lip tightness and seal. Orofacial exercises have also been applied as a rehabilitation tool in patients with lip weakness after a stroke and other neurodegenerative diseases.2 Although normative data for lip strength by age and sex are available, quantitative data in facial paralysis are limited.3 Quantitative labial strength data for patients with facial paralysis can be important in selecting and evaluating the effectiveness of treatment options. In this study, we quantify the effects of facial paralysis on labial strength. We evaluate the effectiveness of nonsurgical injection augmentation of the paralyzed lip in improving labial strength and function.

Methods

This study was performed with approval from the Johns Hopkins Hospital Institutional Review Board. Informed written consent was obtained from all patients. Prospective analysis of patients presenting for treatment of lip incompetence at the Johns Hopkins Hospital between January 1, 2008, and July 31, 2014, due to facial paralysis and facial muscular dystrophy was performed. Patients who had undergone direct surgical lip procedures were excluded. All patients had not received any prior speech therapy. A single speech therapist (H.S.) performed a comprehensive speech and swallow assessment before and 2 weeks after the intervention. A complete oral motor evaluation was performed. The Iowa Oral Performance Instrument (IOPI) (IOPI Medical LLC) was used to measure interlabial pressures from left, central, and right lip locations. The IOPI is a handheld device with pressure-sensing circuitry that displays pressures as measured in kilopascals. For pressure assessment, the IOPI bulb was placed between the lips in the midline, right, and left lip positions, and the patient was asked to press the lips together as firmly as possible. Peak pressures were recorded and the best performance of 3 trials selected. The patients were evaluated for anterior bolus spillage and bilabial sounds. The primary clinical end points analyzed in this study were the pre-treatment and posttreatment interlabial pressure, anterior bolus spillage, and speech quality. No additional lip strengthening exercises were performed. One of us (K.D.B.) performed all the lip injections. Patients were asked to gently close their lips, and the site of interlabial deficiency was outlined (Figure 1). Patients were then asked to blow against pursed lips to identify the site and degree of air escape. Hyaluronic acid–based filler was then injected intramuscularly into the deficient sites until the interlabial gap and air escape were corrected. Statistical analyses were performed using paired t tests and were significant at \( P < .05 \). Then 95% CIs were calculated on the affected and unaffected sides of the lip.

Results

Twenty-two patients with unilateral facial paralysis were evaluated for this study, including 14 women and 8 men with a mean

Figure 1. Photograph of One of the Study Patients With the Site of the Interlabial Deficiency Circled

A, Patient prior to augmentation cheiloplasty. The circle highlights the region of the lip insufficiency and target for injection. B, The same patient after injection, showing the correction and improved lip seal.
Three patients with facial paralysis were evaluated. Central lip strength was reduced in all patients compared with sex-corrected normative data (mean [SD] central lip strength, 5.5 [2.5] kPa in women and 9.6 [4.6] kPa in men) (Figure 2). Compared with the nonparalyzed side, labial strength on the paralyzed side was reduced by 69% (2.2 [1.20] kPa; 95% CI, 1.30-3.15 kPa; for the paralyzed lip vs 7.11 [1.90] kPa; 95% CI, 4.99-9.23 kPa; for the nonparalyzed lip; \( P = .006 \)). After injection augmentation of the paralyzed side, labial strength improved across the entire lip. Mean lip strength improved by 0.66-fold in the central lip from 5.60 to 9.30 kPa (\( P = .009 \)), by 1.4-fold on the paralyzed side from 5.60 to 9.30 kPa (95% CI, 3.89-6.77 kPa; \( P = .006 \)), and 0.4-fold on the unaffected side from 7.11 kPa (95% CI, 4.99-9.23 kPa) to 9.56 kPa (95% CI, 6.89-12.22 kPa; \( P = .12 \)) (Figure 2). Mean lip strength on the paralyzed side improved significantly after injection augmentation but remained lower than that of the nonparalyzed side (Figure 2). Lip strength in the 3 patients with FSHD were uniformly reduced across the entire lip (0 kPa in 2 patients and 1 kPa in 1 patient). After injection augmentation in 1 patient with FSHD, lip strength increased by 6- to 7-fold (Table).

All patients were noted by the speech pathologist (H.S.) to have improved articulation of plosive sounds and decreased anterior spillage after the injection. The effect lasted at least 6 months. There were no injection-related complications.

**Table. Labial Pressure in 3 Female Patients With Facioscapulohumeral Muscular Dystrophy**

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Hyaluronic Acid-based Filler Injection, kPa</th>
<th>Before Treatment</th>
<th>After Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left Lip</td>
<td>Central Lip</td>
<td>Right Lip</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
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<td>0</td>
<td>0</td>
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<td>3</td>
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<td>1</td>
</tr>
</tbody>
</table>

Abbreviation: NM, not measured.

**Discussion**

This study provides quantitative data on the effects of facial paralysis and facial muscular dystrophy on lip strength. Interlabial pressures measured with the IOPI revealed reduction in the paralyzed, central, and nonparalyzed sides of the lip. Treatment of the dystrophic or paralyzed lip with injected hyaluronic acid significantly improves lip strength and function.

The IOPI is effective in quantifying the degree of lip weakness and response to treatment after facial paralysis. The IOPI consists of a small handheld or tabletop component that contains pressure-sensing circuitry, a peak-hold function, and a timer. Thin flexible tubing connects the IOPI bulb with the main component. The bulb is pliable and air-filled, with an approximate internal volume of 2.8 mL. By exerting steady maximal pressure on the bulb, labial pressure is measured digitally in kilopascals. Using the IOPI, Clark and Solomon^4^ recorded central labial strength (mean, 22.4 kPa for women and 33.8 kPa for men) in healthy individuals, which can be used in the evaluation of various disease states. The IOPI can be used to objectively measure the effect of various reanimation techniques, such as functional free muscle transfers and temporalis tendon transfers, on cheek and lip pressure. Weeks et al^5^ evaluated labial strength in patients with stroke compared with healthy adults and found the mean labial strength to be ap-
proximately 25 kPa for healthy adults, with both sides having essentially the same strength characteristics. In our series of patients with unilateral paralysis, labial pressure was reduced across the lip affecting both the paralyzed and nonparalyzed sides. This finding is similar to that measured in patients with stroke and can be explained by the disruption of the sphincter function of the orbicularis oris. Mean labial strength was 69% reduced on the paralyzed side compared with the unaffected side. Injection augmentation improved labial strength across the entire lip affecting the paralyzed, central, and nonparalyzed sides. Although a 1.4-fold improvement in mean labial strength was recorded after injection augmentation of the affected side, it remained lower when compared with the unaffected side.

Hyaluronic acid filler injection has been used extensively for aesthetic soft-tissue augmentation. Injection of hyaluronic acid into the lip to correct lip insufficiency resulting from facial paralysis is, however, not widely reported. To improve lip pressures, the hyaluronic acid is selectively injected deep into the isolated region of the paralyzed orbicularis muscle (Figure 3). A total of 1 to 2 mL of the hyaluronic acid is usually needed to achieve the desired effect. Interlabial pressure measurements and visible correction of interlabial air escape may be used to determine the adequacy of the injection. Labial pressures after hyaluronic acid injection improve on both sides of the lip but to a greater extent on the paralyzed side. Injection of hyaluronic acid as a filler does not directly alter strength of the paralyzed perioral muscles but may influence force generation and labial strength by multiple means. First, the mechanical property of the injected hyaluronic acid confers rigidity to the lip. This effect may be further investigated by comparing the effects of various hyaluronic acids with different cross-linkage and viscosity. In this current study, we used only a single type of hyaluronic acid for uniformity but will compare the effects of various fillers in future investigations. Second, injection of the hyaluronic acid may be improving labial strength by altering the stiffness of the nondynamic extracellular matrix component of the perioral complex. Tissue stiffness is a measure of its ability to resist deformation and ranges several orders of magnitude from adipose tissue. Tissue stiffness is not static but changes in disease state, as seen in facial paralysis and may be improved with extracellular injectable fillers. Third, the improvement in lip pressure generation after hyaluronic acid injection may be indirectly due...
to the improved force generation of the nonparalyzed aspects of the lip (central and nonparalyzed sides) against an increased lip tissue resistance. This finding is suggested by the improvement realized across the lip even in the central and nonparalyzed sides that were not directly injected.

The deficits associated with facial paralysis are functional, aesthetic, and psychosocial. Lip injection with hyaluronic acid has the potential for improving the appearance, function, and social deficits associated with facial paralysis. Patients in this series noted improvement in their ability to drink from a cup and use a straw. These simple tasks can significantly affect the psychosocial quality of life after facial paralysis or stroke. The improvement in lip pressure and the associated functional gain are temporary, and a subsequent injection may be necessary. The hyaluronic acid injection may be used while waiting for spontaneous functional recovery or as an adjunct to definitive reanimation procedures.

Facioscapulohumeral muscular dystrophy is a dominantly inherited muscular dystrophy with a causal deletion on chromosome 4q35 and progressive muscle infiltration and weakness of skeletal muscles. Early involvement of the facial and scapular muscles is a distinctive clinical presentation. Involvement of lip and perioral muscles progressively results in visible functional deficits in smile, bolus containment, and speech. The IOPI measurement in the 3 patients with FSHD was uniformly low across the lip (0 kPa in 2 patients and 1 kPa in 1 patient). Given the comorbidities in this group of patients, a simple minimally invasive approach to improving lip strength is desirable. Lip injection of hyaluronic acid improved interlabial pressures from 0 kPa to 6 and 7 kPa, a 6- to 7-fold increase.

The ultimate utility of therapeutic lip filler injection in facial paralysis is the improvement in quality-of-life measures, such as improved articulation, better discrimination of conversational speech, and correction of anterior bolus spillage, with associated improved confidence in public and social settings. This study reveals improvement in most of the above measures. Because these measurements were performed by the same speech pathologist (H.S.), there is the potential for bias. A more rigorous method using masked professional and nonprofessional observers will be important in objectively quantifying these quality-of-life measures.

Conclusions

Quantifying the labial strength in facial paralysis provides an objective means of measuring the degree of lip weakness and effectiveness of reanimation techniques and therapy. The IOPI is a reliable and simple means of measuring labial strength and cheek strength and can serve as an objective tool in monitoring progression of facial paralysis, facial muscular dystrophy, and treatment response. Simple injection augmentation of the lip using hyaluronic acid can significantly improve lip strength and function. A long-term effect may be achieved with other means of augmentation, such as the use of fat-dermal-fascia grafts. In future studies, we will define the injected volume-pressure change associations to better refine this treatment technique. We will also investigate the effect of various fillers and their effect over time. In addition, we will establish the potential additive effect of lip muscle training and objectively measure the effects on quality of life.

ARTICLE INFORMATION

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Author Contributions: Dr Boahene had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Starmer, Ishii, Byrne, Boahene. Acquisition, analysis, or interpretation of data: Starmer, Lyford-Pike, Ishii, Boahene. Drafting of the manuscript: Starmer, Boahene. Critical revision of the manuscript for important intellectual content: All authors.

Statistical analysis: Starmer, Lyford-Pike, Ishii, Boahene. Administrative, technical, or material support: Ishii, Boahene. Study supervision: Starmer, Byrne, Boahene.

Conflict of Interest Disclosures: None reported.

REFERENCES