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Treating Myofunctional Disorders: A Multiple-Baseline Study of a New Treatment Using Electropalatography

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Abstract

Purpose: This study assessed the benefit of using electropalatography (EPG) in treatment aimed at habilitating individuals with nonspeech orofacial myofunctional disorders (NSOMD).

Method: The study used a multiple-baseline design across 3 female participants who were referred for an evaluation and possible treatment of their NSOMD. Treatment sessions were 30 min and provided twice weekly. Participant 1 received 8 treatments, Participant 2 received 6 treatments, and Participant 3 received 4 treatments. The patterns of sensor activation produced when participants' tongues made contact with the electropalate during saliva swallows were compared with the patterns of age-matched peers. Individualized goals were developed on the basis of these comparisons.

Results: Treatment was generally effective for the established goals. Of the 3 participants, 2 met all their goals, and the 3rd participant made gains across 1 of 2 goals. Participants continued to perform above baseline levels for most targeted goals during testing 5–8 weeks posttreatment.

Conclusion: When used in skilled treatment, EPG has potential as a means of habilitating NSOMD. It may serve as a valuable tool, providing the clinician and client with information that allows for individualized treatment planning.

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Orofacial myofunctional treatment has been recommended as a means of training lingual resting and functional patterns (American Speech-Language- Hearing Association [ASHA], 2014). Although ASHA describes nonspeech orofacial myofunctional disorders (NSOMD) management as a professional role for speech language pathologists (ASHA, 2007), little guidance has been offered regarding forms of effective treatment. Clinicians working with individuals with NSOMD can face a clinical challenge when evaluating or providing feedback about the movement of the tongue at rest and/or during the swallow. Parting the lips can disrupt the lingual pattern (Knosel, Klein, Bleckmann, & Engelke, 2012; Peng, Jost-Brinkmann, Yoshida, Chou, & Lin, 2004), so it is difficult to provide accurate, individualized feedback to clients about their changing performance in response to treatment, unless instrumentation is used.

To date, various intervention strategies have been used to address NSOMD. Physical exercises to stretch, tone, strengthen, and develop proper neuromuscular proprioception have been described frequently (Korbmacher, Schwan, Berndsen, Bull, & Kahl-Nieke, 2004; Moeller, 2008; Rampp & Pannbacker, 1977; Richardson, 2003). Published treatment studies have included a broad age range of participants from 3 years of age (Berndsen, Bull, Kahl-Nieke, Korbmacher, & Schwan, 2004) through adulthood (Barreto e Silva et al., 2007) and are mostly of single-subject design. None of these studies reported the use of instrumentation to determine patterns of lingual–palatal contact pre- and posttreatment. Researchers either parted the lips during the swallow to evaluate the tongue movement, or they described only a broad movement of the tongue as protruding beyond the border of the lips.

There are few studies that describe treatments aimed at modifying tongue thrust swallow patterns, a subcategory of NSOMD. Techniques used have included a behavioral approach that involved pushing the protruding tongue into the oral cavity with a spoon (Thompson, Iwata, & Poynter, 1979) or applying downward pressure to the midportion of the tongue during food presentation (Ganz, 1987; Gibbons, Williams, & Riegel, 2007). External support applied to the participant's jaw during swallowing has been described as useful (Ganz, 1987). Sensory approaches have included olfactory stimulation prior to food presentation (Ganz, 1987) or application of an oral stimulator designed to improve orofacial sensory-motor function (Fischer-Brandies, Avalle, & Limbrock, 1987). Despite some of the successes reported, replication studies have not followed.

Aside from orofacial myofunctional approaches, fixed and removable oral appliances have been described as an approach to treating NSOMD. Fixed tongue cribs involve cementing wires from the first molars on one side to the other. This creates a mechanical barrier for the purpose of holding the tongue behind the incisors during the swallow and redirecting the tongue to a more normal swallow position by forcing the midportion of the tongue backward and upward. Complications have included submerging of the appliance into the mucosa, causing pain and inflammation (Singh, Prerna, & Jain, 2011). Removable tongue cribs can decrease problems of submergence, but unfortunately they have poor client compliance (Schott & Göz, 2010). Tongue bead appliances, such as the "Lingual Pearl" (Ritto, 2010; Ritto & Leitão, 1998) and the modified Bluegrass appliance (Baker, 2000), have been used as a tongue retraining approach. They consist of a spinnable bead that is positioned behind the anterior front teeth and held in place by a dental appliance. Clients are asked to pull the bead toward the posterior portion of the mouth as a form of exercise, and they are taught to keep the tongue posterior to the bead when swallowing, using the bead as a placement cue. Some success has been reported, but with more severe cases of tongue thrust, the beads may not be effective (Abraham et al., 2013).

Electropalatography (EPG) is a visual biofeedback device used in clinical and research practices to depict lingual–palatal timing and contact patterns. Using biofeedback is a foundational concept to the principles of motor learning necessary for relatively permanent change in motor behavior (Schmidt & Lee, 2011). Because treatment strategies targeting disorders associated with tongue movement are generally behavioral in nature (Logemann, 2006) and biofeedback has proven to be a valuable tool in modifying behaviors, incorporating EPG into orofacial myofunctional treatments may be a promising option. Visual feedback may be particularly beneficial for those with tongue thrust, as they may demonstrate altered oral sensory perception (Premkumar, Venkatesan, & Rangachari, 2011).

Although EPG has been used to assess lingual contact patterns of individuals with NSOMD (Cayley, Tindall, Sampson, & Butcher, 2000;

Mantie-Kozlowski & Pitt, 2013), the benefits of EPG have not been explored for habilitation. The present study offers an innovative approach to orofacial myofunctional treatment by incorporating biofeedback from EPG into the treatment design. This tool provides information about the pattern of lingual contact against the artificial palate, although clinicians must deduce which anatomical portion of the tongue is making contact. With this in mind, the clinician can predict the dynamic lingual–palatal timing and contact patterns associated with the swallow by combining EPG feedback information with knowledge of the anatomy and physiology of the tongue and the shape of the client's palate (Gibbon & Lee, 2007). Clinicians who use EPG in their approach to modify lingual behaviors may increase the individualization of treatment for clients with NSOMD.

Method

The university institutional research ethics board approved this study.

Electropalatography Instrumentation

EPG data were collected using the Complete Speech Palatometer V 1.0 system (Complete Speech, 2012). The Complete Speech Palatometer system consisted of an approximately 0.5-mm thick custom-formed retainer with thin flexible printed circuits that conformed to the shape of the participants' palates (i.e., artificial palate, electropalate, SmartPalate), DataLink, a USB cable connected between the DataLink and computer, and the associated computer software. The water-resistant electropalates contained 126 gold-plated contacts, including two lip closure sensors and two gum contacts (see **Figure 1**). For Participant 3 (P3), who had a smaller oral cavity, the electropalate was modified to 104 gold-plated contacts to accommodate her smaller palate. The removed contacts are displayed in **Figure 2.** The contact sensors were sampled at 100 Hz.

The Complete Speech Palatometer system allowed for unlimited length recordings that could be played back in real time and slow or stop motion. This information was relayed to a computer, which displayed a layout closely resembling the actual electrode placement within the oral cavity. Activation of a sensor was accomplished by

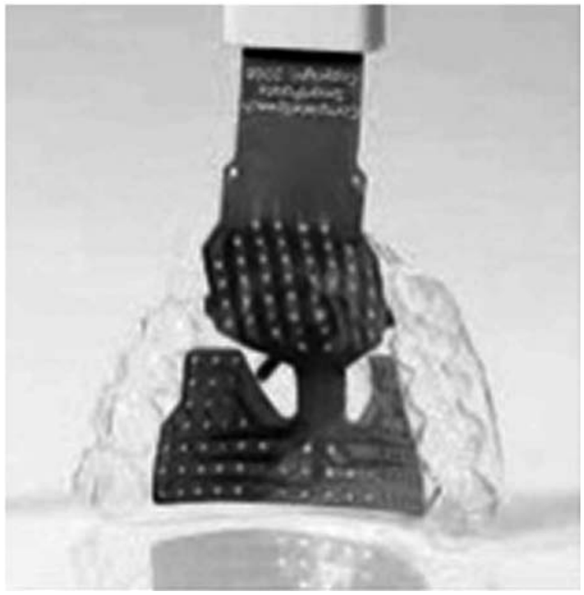

Figure 1. Electropalate. Copyright 2012, Complete Speech. Reprinted with permission.

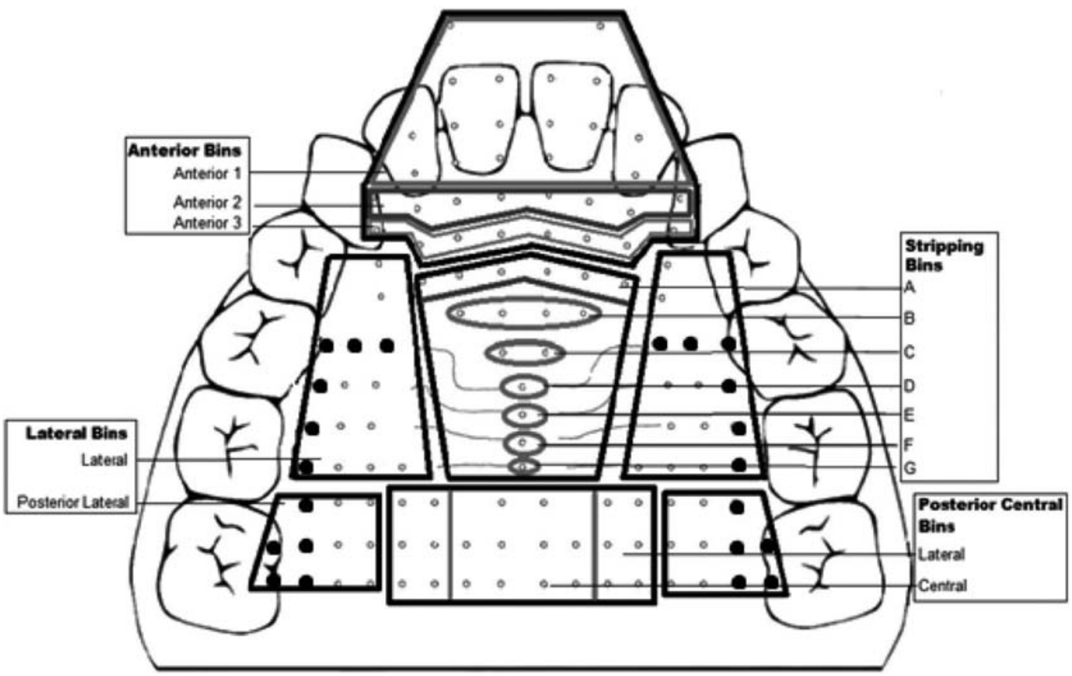

Figure 2. Compartmentalization of the electropalate into four primary palatal bins: anterior, lateral, stripping, and posterior-central. The anterior bin is further subdivided into Anterior 1, 2, and 3. The lateral bin is further subdivided into lateral and posterior-lateral. The stripping bin is further subdivided into A through G. The posterior-central bin is further subdivided into lateral and central. Bolded sensors were not present in the modified palates. Reprinted with permission from the International Journal of Orofacial Myology.

tongue-to-artificial-palate contact, with a corresponding visual display of the contact location. The information was saved on an external hard drive.

In order to describe the participants' lingual–palatal contact in an operationalized manner, the sensor display was divided into four palatal bins labeled as follows: anterior, lateral, stripping, and posterior-central. To fully represent the pattern of lingual–palatal contact, the bins were further subdivided. The anterior bin was divided into Anterior 1, Anterior 2, and Anterior 3. The stripping bin was divided in an anterior to posterior manner and labeled A through G. The posterior-central bin was divided into posterior-central-central and posterior-central-lateral. The lateral bin was divided into lateral and posterior lateral (see Figure 2).

Bin activation was tracked frame by frame, progressing in 0.01-s increments. The order in which the bins activated and/or deactivated was logged. The criteria for activation of the anterior, lateral, and posterior central bins represented the minimum number of activated individual sensors needed to create a lingual–palatal seal. Activation ratios follow. The denominator represents the total number of sensors within the bin, and the numerator represents the number of sensors within the bin that had to be activated by lingual–palatal contact; anterior bin: Anterior 1 (6/18 sensors), Anterior 2 (2/8 sensors), and Anterior 3 (2/8 sensors); the lateral bin (12/30 sensors; 10/18 sensors for the modified palates). The value for activation of the stripping bins was a minimum of 50%. Activation ratios were as follows; stripping bin: A (3/6 sensors), B (2/4 sensors), C (1/2 sensors), D (1/1 sensors), E (1/1 sensors), F (1/1 sensors), G (1/1 sensors); the posterior-lateral bin (6/22 sensors; 6/12 sensors for the modified palates); the posterior-central bin: posterior-central-central (4/10 sensors) and posterior-central-lateral (4/12 sensors). A detailed description of the coding procedures is described elsewhere (Mantie-Kozlowski & Pitt, 2013).

Design

The study used a multiple-baseline design across participants. Individual intervention plans were developed for each participant. The study was conducted over 7 weeks. A postintervention probe was collected 5–8 weeks after intervention was terminated.

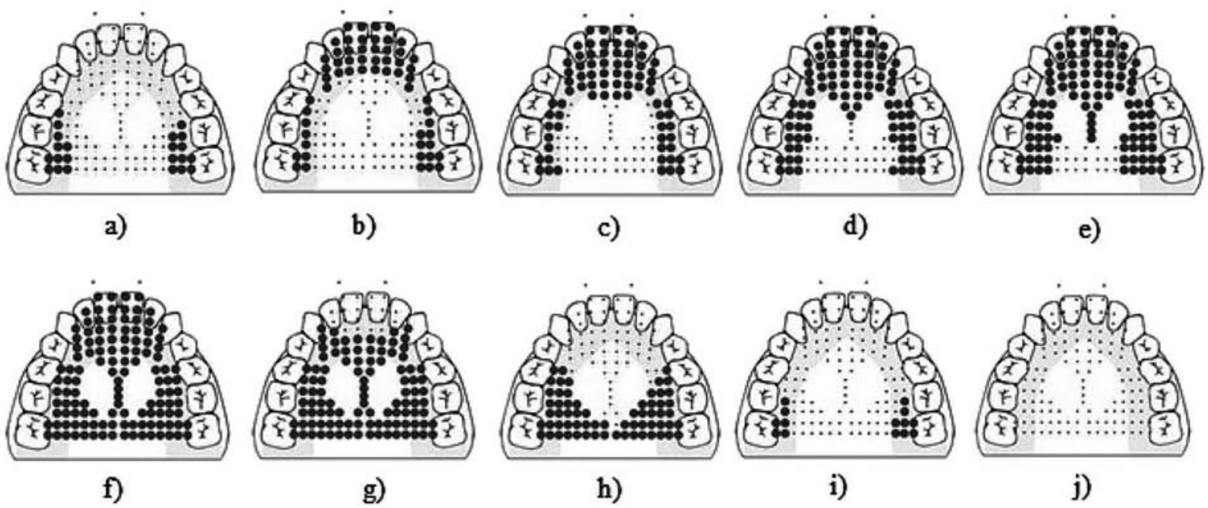

Figure 3. Pattern of lingual–palatal contact displayed by individuals without non-speech orofacial myofunctional disorders (NSOMD). The four stages represented are prepropulsion (a–b), propulsion (c–f), postpropulsion (f), and release (g–j). Bolded dots represent activated electrodes. Reprinted with permission from the International Journal of Orofacial Myology.

Individualized goal(s) were established by comparing each participant's performance in terms of lingual–palatal timing and patterns of contact to age-matched peers without NSOMD, which have been published previously (Mantie-Kozlowski & Pitt, 2013). The activation pattern for adults and children without NSOMD were the same (see **Figure 3**), although durations were noted to be longer for the child (see **Table 1**). The stages, as described below, were used to establish the target goals of lingual–palatal contact patterns for the participants in the study.

Stage 1. Prepropulsion involved the creation of a lingual seal as defined by activation of the lateral and anterior bins. The bins did not have to be activated in a systematic order. Lingual seal completion had to be accomplished before initiation of Stage 2 (see Figure 3, Panels a–b).

Stage 2. Propulsion involved stripping action as defined by sequential activation of the stripping bin in a direction of anterior to posterior, followed by activation of posterior-central bins until full contact was reached (activation of all bins; see Figure 3, Panels c–f).

Table 1. Mean duration of targeted swallowing stages for adults and children without non-speech orofacial myofunctional disorders.

	Prepropulsion		*Propulsion*		*Postpropulsion*		*Release*	
Group	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Adult	0.40	0.11	0.31	0.25	0.72	0.21	0.48	0.04
Child	0.32	0.21	0.36	0.23	1.43	0.48	0.32	0.18

Stage 3. Postpropulsion was the period between initial full contact and initiation of final release (see Figure 3f).

Stage 4. Release involved the directional deactivation of all bins from anterior to posterior (see Figure 3, Panels g–j).

Research Participants

Three females, who were referred to a university speech and hearing clinic for assessment and treatment of NSOMD, participated in the study. All three participants underwent a noninstrumental swallow evaluation conducted by a certified speech language pathologist. The strength and range of motion of the jaw, lips, and oral tongue were assessed during nonswallowing tasks and were considered unremarkable for all participants. However, all participants contracted the buccinator and mentalis muscles to a degree that it drew the examiner's attention to the lip and chin areas during swallows. No signs or symptoms of pharyngeal or esophageal complications were assessed or reported. The lingual–palatal contact patterns were assessed using EPG on 15 saliva swallows.

Participant 1

Participant 1 (P1) was 44 years of age. P1's presenting concerns were cosmetic. P1 indicated that she felt self-conscious about her swallowing pattern, claiming that she received negative attention as a result of both her nutritive and non-nutritive swallows. P1 reported a history of orthodontic relapse and was considering her third set of dental braces to correct her open bite. Upon evaluation, we identified P1's lingual–palatal contact pattern as described below.

Stage 1: Prepropulsion. The swallow was initiated within the anterior bin on all trials; however, on 53% of the swallows the Anterior

2 sub-bin was activated prior to the Anterior 1 bin. On 27% of occasions, the Anterior 3 sub-bin was activated initially, and then activation sequentially moved forward to the Anterior 1. On 20% of occasions, initial contact was made in the Anterior 1 sub-bin. After anterior bin contact was made, the lingual seal was accomplished. This last pattern was consistent with her age-matched peer. The average duration was 0.32 ± 0.90 s.

Stage 2: Propulsion. Stripping action proceeded in an anterior to posterior motion with Sub-Bins A through G sequentially activating, which matched the pattern of her age-matched peer. The average duration was 0.15 ± 0.25 s.

Stage 3: Postpropulsion. The pattern mirrored that of her age-matched peer. The average duration was 1.14 ± 0.23 s.

Stage 4: Release. Directional deactivation of bins was accomplished with a posterior-to-anterior deactivation on 20% of the swallows and an anterior-to-posterior deactivation (the pattern of her age-matched peer) on 80% of the swallows. The average duration was 0.49 ± 0.17 s.

P1 required intervention goals for Stages 1 and 4 (see **Table 2**).

Participant 2

Participant 2 (P2) was 8 years of age. P2's father was concerned about negative stigmatization of his daughter because of her "messy eating." Food escaped her oral cavity when eating, and residues of masticated material were noted on her lingual surface and in her lateral sulci. She had occasional difficulty managing her saliva. At the time of treatment, P2 was receiving occupational therapy to work on fine motor skills. She was reportedly doing well with her academic work, and her speech and language skills were unremarkable. P2 had been diagnosed with an open bite by her orthodontists but had not received any orthodontic management. Upon evaluation, we identified P2's lingual–palatal contact pattern as described below.

Stage 1: Prepropulsion. The lingual–palatal contact pattern mirrored that of her age-matched peer with the creation of a lingual seal prior to Stage 2. The average duration was 0.40 ± 0.24 s.

Stage 2: Propulsion. Like her age-matched peer, P2 performed sequential anterior-to-posterior stripping after lingual seal completion. The average duration was 0.24 ± 0.17 s.

Stage 3: Postpropulsion. Full contact was made, but it was not spontaneously released, becoming the posture of her tongue at rest. A dura-

Table 2. Treatment goals for each participant.

Participant (P)	*Goals*
P1	Stage 1: P1 will create a lingual seal with activation of the anterior bin progressing from anterior to posterior on 5 of 5 saliva swallows completed in the absence of external feedback. Stage 4: P1 will deactivate bins from anterior to posterior on 5 of 5 saliva swallows completed in the absence of external feedback.
P2	Stage 3: P2 will spontaneously release her swallow within 1.91 s of full contact on 5 of 5 saliva swallows completed in the absence of external feedback. Stage 4: P2 will deactivate bins from anterior to posterior on 5 of 5 saliva swallows completed in the absence of external feedback.
P3	Stage 1: P3 will complete a lingual seal prior to the initiation of stripping action on 5 of 5 saliva swallows completed in the absence of external feedback. Stage 2: P3 will demonstrate directional activation of the stripping bin from anterior to posterior, followed by activation of posterior-central bins until full contact is reached on 5 of 5 saliva swallows completed in the absence of external feedback. Stage 3: P3 will demonstrate only a single stripping action on 5 of 5 saliva swallows completed in the absence of external feedback. Stage 3: P3 will demonstrate postpropulsion duration of 0.93 s or less on 5 of 5 saliva swallows completed in the absence of external feedback. Stage 4: P3 will deactivate bins from anterior to posterior on 5 of 5 saliva swallows completed in the absence of external feedback.

Goals were established for all participants through comparison of the lingual–palatal time and contact patterns of an age-matched peer without nonspeech orofacial myofunctional disorders.

tion for this stage could not be established as there was no transition to Stage 4. This was unique to this participant, as her age-matched peer routinely transitioned to Stage 4 spontaneously.

Stage 4: Release. Directional deactivation of electrodes was not accomplished spontaneously. Full contact was maintained unless verbally prompted by the researcher to release. When prompted, the average duration was 0.33 ± 0.19 s. Upon release, the pattern was posterior to anterior on 67% of the swallows and anterior to posterior (the pattern displayed by her age-matched peer) on 7% of swallows. On 27% of occasions, full contact was not released during the recording. The examiner confirmed that a full swallow was being completed through laryngeal palpation paired with EPG on five additional swallows.

P2 required intervention goals for Stages 3 and 4 (see Table 2).

Participant 3

Participant (P3) was 21 years of age. P3 reported being self-conscious about what she had been told might be a tongue thrust. During meals, P3 used a liquid wash after swallows of masticated material because she had difficulty clearing food from her oral cavity. She wore a permanent retainer, which had been placed after her dental braces were removed at age 16. She indicated that her orthodontist had also provided her with a list of tongue exercises when she had her dental braces removed, but she had not performed them routinely. At the time of her evaluation, she was unable to demonstrate any of the exercises or describe their purpose. Upon evaluation, we identified P3's lingual–palatal contact pattern as described below.

Stage 1: Prepropulsion. On 67% of the trials, the lingual seal was not completed until after initiation of the stripping action. This was unlike her age-matched peer, who always created a seal before initiating Stage 2. The average duration was 0.23 ± 0.10 s.

Stage 2: Propulsion. The average onset time of propulsion began at 0.19 ± 0.99 s after the initiation of Stage 1. The pattern of activation of the stripping bin was inconsistent. On 7% of the swallows, there was a sequential anterior-to-posterior strip within the stripping bin. The other 93% showed no directional activation. On 73% of the swallows, the posterior-central-central sub-bin was activated during the stripping action in sub-bins. On 27% of occasions, the posterior-central-central sub-bin was activated after the stripping was completed. The average total duration was 0.24 ± 0.90 s.

Stage 3: Postpropulsion. A "re-strip" while in the postpropulsion stage was noted on 33% of the swallows, in which P3 repeated the sequential activation of electrodes in the stripping bin, which was unique to this participant. The average duration was 1.99 ± 0.69 s.

Stage 4: Release. Directional deactivation of bins occurred posterior to anterior, the opposite direction of her age-matched peer 100% of the time. The duration was 0.43 ± 0.20 s.

P3 required intervention goals for all stages of the swallow (see Table 2).

Experimental Procedure

Electropalographic baseline. Prior to intervention, baseline measures were collected on all participants. For the two participants remaining in baseline after Week 1 (P2 and P3), pretreatment data points on all stages of lingual palatal contact were collected twice a week to parallel participants receiving intervention. This resulted in three baseline data points for P1, five for P2, and seven for P3. Each baseline data point represents the average duration (in seconds) or the percentage of time the participant matched the pattern of her age-matched peer without NSOMD for each stage of lingual–palatal contact and was calculated from five saliva swallows in the absence of augmented (visual feedback from the EPG or verbal feedback from the clinician) feedback.

The participants wore a pseudopalate for a desensitization period of approximately 30 min as described in previous studies, prior to data collection (Chi-Fishman & Stone, 1996; Gibbon, Hardcastle, & Moore, 1990; Searl, Evitts, & Davis, 2006). The participants drank small sips of water between the recorded saliva swallows to ensure that they maintained a moist oral cavity. Rest periods of 15–60 s were provided between all swallows.

Individual intervention. Sessions were 30 min long and provided two times per week. P1 received eight intervention sessions, P2 received six, and P3 received four. The treatment portion of the study was terminated at the end of 5 weeks as the family members of P2 requested a break from treatment so they could take a vacation together. At the end of the treatment session, data points used to track participant performance were obtained and calculated following the same procedure used during baseline but without augmented feedback.

Acquisition of the motor sequence of typical lingual– palatal contact during the swallow was accomplished by offering the participants a visual model of the contact pattern. Both the participant and clinician wore a custom-fit electropalate so the clinician had the option of modeling elements of the complex sequence if necessary, for the participant to achieve success. However, preloaded swallows from age-matched peers were also provided so that the participant could compare on a split screen her dynamic EPG swallow pattern with the prerecorded swallow from her age-matched peer without NSOMD. As soon as the participant demonstrated emerging understanding of the movement (three out of three attempts of the element with visual feedback), she was encouraged to perform the sequence as a single skilled behavior.

Manipulation of the form, frequency, and timing of biofeedback was a component of this treatment program. Biofeedback in the form of “knowledge of performance” was used to describe the nature or quality of the movement pattern through visual biofeedback from the EPG. The clinician also offered qualitative feedback about the movement pattern of the tongue. This form of high-frequency augmented feedback has been found to be associated with increased motivation and enhanced performance during training (Lee, White, & Carnahan, 1990). However, lower frequency feedback has been found to be associated with long-term learning, and so the feedback was faded by turning the computer screen away from the participant and limiting the verbal feedback from the clinician once the participant met her goal on eight of 10 swallows during the session (Winstein & Schmidt, 1990). The feedback provided transitioned into “knowledge of results.” Knowledge of results refers to information about the movement outcome in relation to the goal and is provided after the completion of a movement. In response to the participant’s performance, the clinician said, “That’s it,” “That’s close,” or “No, not quite.” A postfeedback delay interval of approximately 4–5 s after the task was completed was allowed, as delayed feedback may promote maintenance of a trained skill (Schmidt & Wulf, 1997). The “knowledge of results” was initially provided after each swallow, but once three of five swallows were completed accurately, the feedback was provided only after the participant completed five swallows. Mastery of a single intervention goal was not required before the participant moved to other goal(s), and all goals were addressed during each treatment session.

Postintervention. Postintervention measures of targeted lingual–palatal timing and contact patterns were collected 5– 8 weeks after interventions were completed to assess retention of intervention goals. Data points were calculated following the same procedure used during baseline and treatment.

Results

All data were collected, analyzed, and coded together by both researchers. Discrepancies were negotiated until an agreement was reached.

Participant 1

P1 had intervention goals for modification of the lingual–palatal contact patterns demonstrated during the stages of prepropulsion and release. During prepropulsion, P1 initiated her swallow with a forward gesture of the tongue between the anterior teeth, interrupting lingual seal creation. Additionally, the direction of lingual palatal release was posterior to anterior rather than anterior to posterior on 20% of occasions. For prepropulsion, she first reached 100% accuracy on Treatment Session 5 and then again on Sessions 7 and 8 (see **Figure 4**). At 5–8 weeks postintervention, P1 was 80% accurate. For the release stage, she had a random baseline and reached 100% accuracy on Treatment Session 2. Performance then remained stable throughout the intervention (see Figure 7). At 5–8 weeks postintervention, accuracy was 60%.

Participant 2

P2 had intervention goals for modification of the lingual–palatal timing and contact patterns demonstrated during the stages of postpropulsion and release. P2 achieved full contact, but deactivation of electrodes was rarely accomplished spontaneously, and this lingual position became her resting posture. A goal was established for her to spontaneously release contact within 1.91 s of full contact. This time represented the outside limit of the durations of her age-matched peer. For the postpropulsion stage, P2 had a stable baseline above 4 s. Durations remained above 4 s until Session 4. By Session 6, her durations decreased to 1.6 ± 0.32 s (see Figure 6). At 8 weeks postintervention, the average duration was 2.4 ± 1.14 s. When release occurred, it was predominantly in the posterior-to-anterior direction rather than anterior to posterior. The performance of P2 for the release stage remained random over the course of the study (see Figure 7). At 5–8 weeks postintervention, accuracy was 60%.

Participant 3

P3 had intervention goals for modification of the lingual–palatal timing and/or contact patterns for all four stages. P3 frequently started

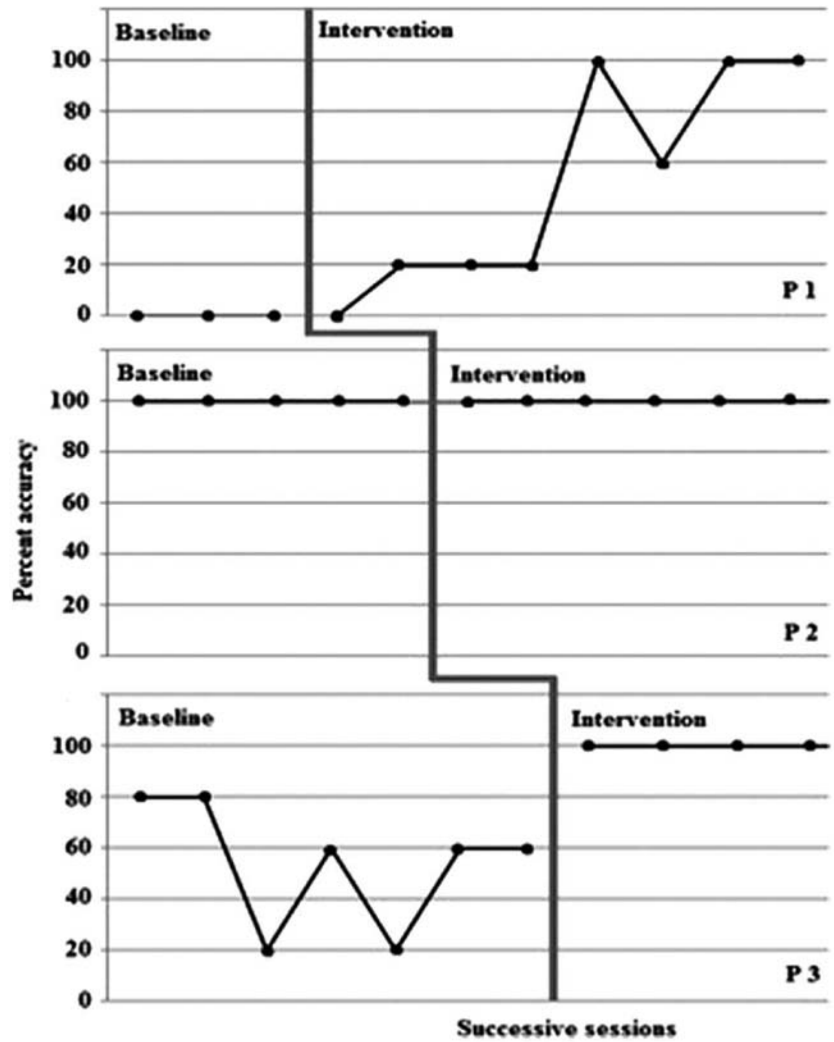

Figure 4. Multiple-baseline analysis of each participant's performance during the prepropulsion stage in baseline and treatment is depicted. Circles represent the participant's average percent accuracy calculated from five swallows in the absence of augmented feedback. P = Participant.

lingual stripping before full lingual seal creation. Her propulsion lacked directionality, and her postpropulsion durations were excessive. Additionally, her release was posterior to anterior rather than anterior to posterior. For the prepropulsion stage, P3 had a random baseline before reaching 100% accuracy on Treatment Session 1. Performance remained consistent throughout intervention (see Figure

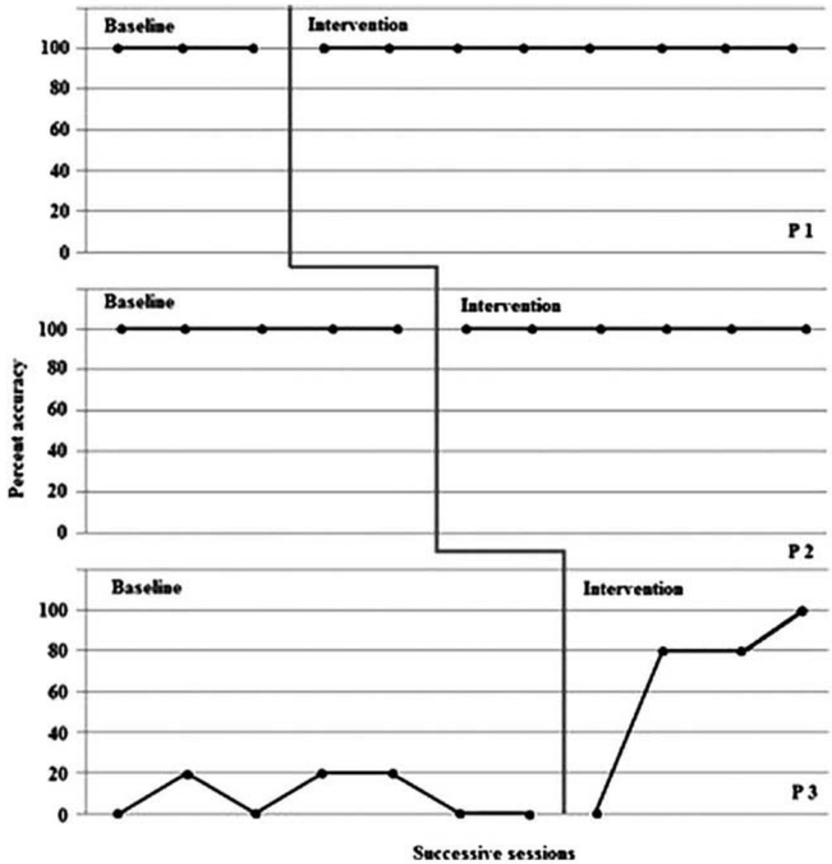

Figure 5. Multiple-baseline analysis of each participant's performance during the propulsion stage in baseline and treatment is depicted. Circles represent the participant's average percent accuracy calculated from five swallows in the absence of augmented feedback.

4). At 5–8 weeks postintervention, performance remained at 100% accurate. For the propulsion stage, P3 had a random baseline, reaching 100% accuracy at Session 4. She then remained stable throughout intervention (see **Figure 5**). At 5–8 weeks postintervention, performance was 60% accurate. For the postpropulsion stage, baseline durations were between 2.07 ± 0.27 s and 1.48 ± 0.23 s, which were excessive. A goal was established to decrease this duration to 0.93 s, which represented the upper limit of her age-matched peer. Durations decreased to 1.17 ± 0.24 s during her fourth treatment session (see **Figure 6**), just meeting her goal when standard deviations were included.

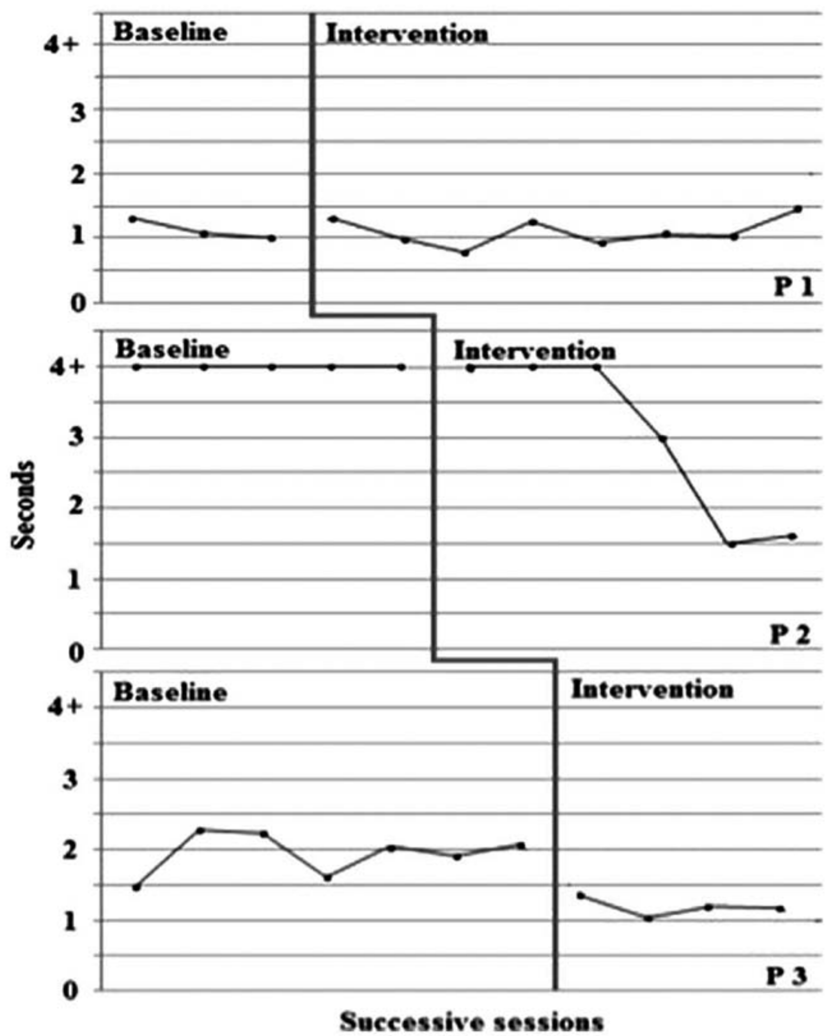

Figure 6. Multiple-baseline analysis of each participant's performance during the postpropulsion stage in baseline and treatment is depicted. Circles represent the participant's average duration calculated from five swallows in the absence of augmented feedback.

At 8 weeks postintervention, the average duration was 1.14 ± 0.54 s. She had a stable baseline of 0% accuracy for the release stage, with the exception of one data point of 20% accuracy. By Session 2, 100% accuracy was achieved and remained stable throughout intervention (see **Figure 7**). At 5–8 weeks postintervention, accuracy was 60%.

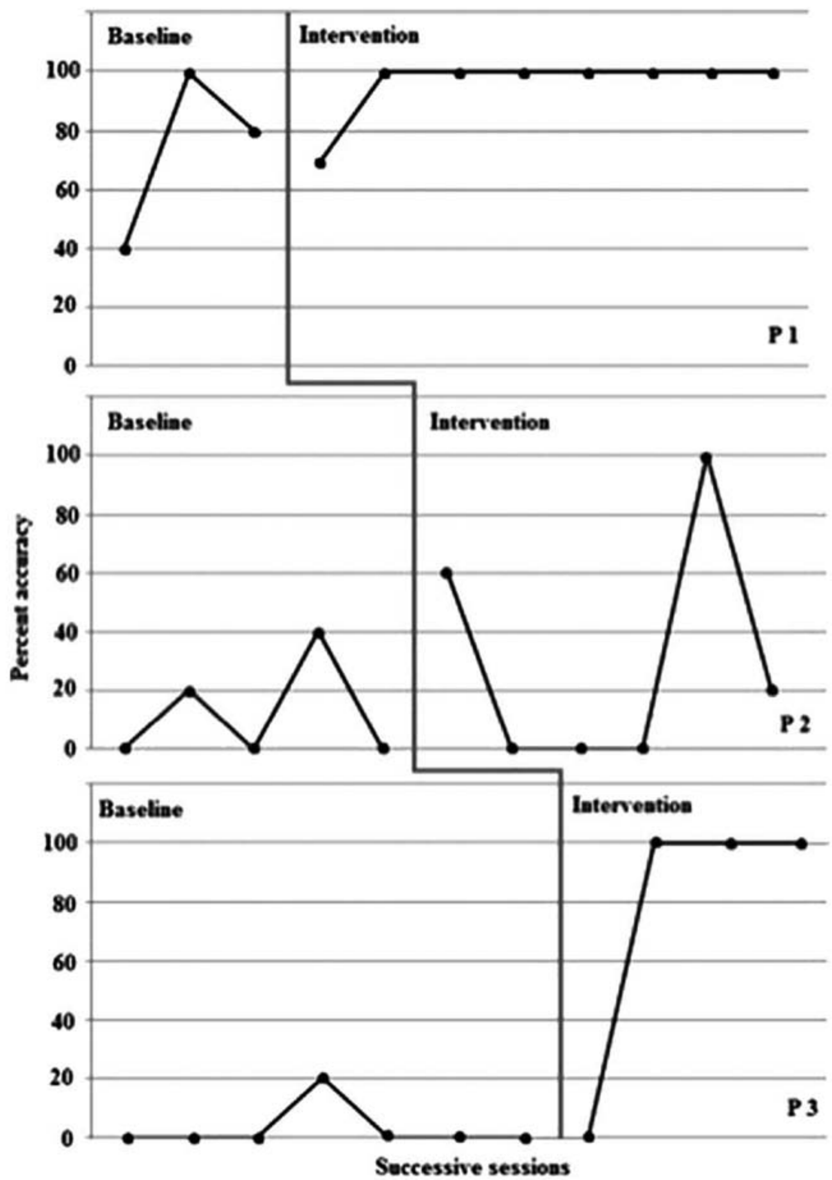

Figure 7. Multiple-baseline analysis of each participant's performance during the release stage in baseline and treatment is depicted. Circles represent the participant's average percent accuracy calculated from five swallows in the absence of augmented feedback.

Discussion and Conclusion

Our study assessed an innovative approach to treatment aimed at habilitating lingual movements associated with NSOMD by incorporating EPG biofeedback and the principles of motor learning into the treatment design. Although biofeedback is common practice in many rehabilitative fields, biofeedback in the form of EPG for remediating NSOMD has received minimal attention. This multiple-baseline design study demonstrates promise for incorporating biofeedback into the treatment approach. However, larger scale studies are needed to establish generalization.

The participants in this study sought intervention for concerns related to their swallow pattern, which were both nutritive and nonnutritive in nature. The challenges of preparing and efficiently transporting a bolus posteriorly during eating resulted in a functional disorder. Detrimental social effects exist for those with NSOMD (Ganz, 1987), and the participants of this study expressed these apprehensions as well.

P1 had a lingual pattern that has been characterized as a tongue thrust (Yamaguchi & Sueishi, 2003) in that she moved her tongue progressively forward from Anterior 2 or 3 to Anterior 1 and then initiated her swallow with a forward gesture of the tongue between the anterior teeth, which was visible to others. P1 was highly motivated to alter this tongue thrust pattern because of self-consciousness and negative attention.

The father of P2 was concerned that his daughter might be stigmatized because she had some difficulty managing saliva and because, during meals, she had challenges maintaining a bolus in her oral cavity. P2 had an overjet, and her dentist was worried that her tongue carriage might be contributing to this condition. Rather than releasing her tongue from her palate following propulsion, P2 maintained full lingual–palatal contact, with her tongue resting against her anterior and lateral teeth becoming her resting tongue posture. This prolonged lingual–dental contact has been linked to dental changes and may influence the oral occlusion (Mason, 2011; Mason & Proffit, 1974).

P3 expressed concerns that were similar to P1. Additionally, she described challenges in moving a bolus posteriorly. P3 initiated her stripping action before creating a lingual seal, and her stripping movement often lacked anterior-to-posterior direction. These factors may account for her reported difficulty in bolus transport, as tongue– palate contact during swallowing not only provides the anterior and lateral seals necessary for bolus and saliva containment but also derives the force needed for bolus propulsion (Chi-Fishman & Stone, 1996).

With twice weekly intervention sessions of 30 min duration, these participants made gains toward altering their lingual–palatal timing and contact patterns to that of their age-matched peers. Two of the three participants met all their goals (P1 and P3). By completion of the study, the timing of lingual movements were within one standard deviation of their age-matched peer without NSOMD, and the contact patterns were characteristic of the targeted pattern. P2 met her goal of decreasing postpropulsion duration that was within the range of her age-matched peer. However, she was not able to demonstrate stable progress toward her goal of directional release. P2 did not perform a spontaneous release at the initiation of treatment. Although both goals were addressed at each session, the clinician prioritized the goal of decreasing postpropulsion duration. Once P2 began releasing lingual–palatal contact, greater attention could be directed to the pattern of directional release. With improved directional release, it was anticipated that P2's ability to maintain the bolus within the oral cavity would also improve.

All participants recorded postintervention performance probes above baseline for all of their treatment goals with one exception. P1's release goal during her postintervention probe was 60% accurate in comparison to a random baseline of between 40% and 100% accuracy. For most of the goals, the findings demonstrate that gains made in this short treatment period were still evident up to at least 5–8 weeks after treatment cessation.

Results from our data suggest that when used in skilled treatment, EPG has potential as a means of establishing lingual–palatal timing and contact patterns associated with normal oromyofunction. EPG may serve as a valuable tool that provides the clinician and client with detailed information on lingual–palatal contact. Because parting the lips can disrupt the lingual pattern during the swallow, the true movement of the tongue cannot be characterized. EPG is one instrumental method that may be used to facilitate treatment of those with NSOMD.

Future Directions and Limitations

The findings of this study are encouraging. However, given the limited number of participants in this study, larger scale investigations of EPG as a habilitation tool for individuals with NSOMD are warranted.

Aside from altering atypical lingual–palatal contact patterns of non-nutritive swallows, the benefits of EPG for orofacial rest posture therapy may warrant investigation. Although EPG may add cost to behavioral treatment of NSOMD, the cost versus benefit may equalize should biofeedback facilitate a more expedient response to intervention than might otherwise occur without it.

The use of EPG for habilitating swallowing has some limitations. As noted, EPG displays the pattern of contact of the tongue against the artificial palate but does not demonstrate the anatomical portion of the tongue creating contact. This must be deduced by the clinician, on the basis of the shape of an individual's palate and knowledge of the anatomy and physiology of the tongue (Gibbon & Lee, 2007). Clinicians must have these competencies if they want to use EPG effectively in treatment. Additionally, whether the artificial palate itself influences lingual–palatal timing and contact patterns associated with swallowing has not been studied.

For individuals with NSOMD, there is interest in understanding the swallow patterns displayed during both non-nutritive and nutritive swallows. Although this study focused on non-nutritive swallows because of the high frequency in which they habitually occur, the pattern displayed by individuals with NSOMD during nutritive swallows may also be of interest. The feasibility of using EPG for nutritive swallows needs further study.

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