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Tongue palate contact during selected vowels in normal speech

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Abstract

Objective: Previous research using electropalatography (EPG) has revealed that high vowels are vulnerable to articulation errors in cleft palate speech. The error involves complete tongue palate contact, which obstructs normal airflow through the mouth and increases nasal airflow. This study used EPG to provide a more detailed description of typical tongue palate contact for high vowels than currently exists.

Design: EPG and acoustic data were recorded for multiple repetitions of monophthongs /i/, /u/, /a/ and diphthongs, /ai/, /oi/, /au/.

Participants: Ten typical English-speaking adults.

Measures: Two measures were taken from EPG data during vowels; one identified EPG patterns with complete tongue palate contact and a second calculated percentage contact at 5 time points.

Results: None of the vowels had EPG patterns with complete tongue palate contact. The amount of contact varied for the different vowels, at the 5 time points throughout the vowels and also between speakers. When contact occurred, it was located in the posterior, lateral regions of the palate forming a central groove that was free of contact.

Conclusion: Complete tongue palate contact during vowels is not a feature of typical English speech and can be considered an error pattern. The normative date provided in this study will be useful to speech-language pathologists who use EPG in their clinical work. The implications of the findings are discussed in relation to the assessment of vowels in cleft palate speech.

Key words: cleft palate, electropalatography (EPG), vowels, articulation disorder, speech.

Introduction

Most studies that investigate articulation in cleft palate speech focus on consonant errors, with vowels receiving relatively scant attention. The lack of attention may be due to the widely held view that the “intelligibility of vowel sounds in cleft palate is rarely affected” (Morley, 1970). Studies using perceptually-based (listener) evaluations have supported the view that vowel errors are rare. An early study by Spriestersbach et al. (1956) found that 96% of vowels were correctly articulated when nasalization was not counted as an error. This is consistent with Moll (1969), who reviewed vowel articulation in cleft palate speech and concluded that, although vowels were often nasalized, “vowel articulation in the cleft palate population is not greatly deviant”. In summary, early studies suggested that vowel articulation is rarely abnormal, but only when nasalization is excluded as an error. This is a major caveat; abnormal resonance is a relatively frequent consequence of cleft palate, and when its presence has an adverse effect on vowel quality (Lewis et al., 2000; Peterson-Falzone et al., 2001).

Classifying articulation errors separately from nasalization is a feature of many clinical speech assessment procedures. This separation is justified for diagnostic purposes because it helps to identify whether speech difficulties are due primarily to abnormal functioning of the velopharynx on the one hand, or due to abnormal functioning of the articulators, such as the tongue, on the other. However, recent research has shown that a particular type of articulation error affecting vowels could be closely linked with increased nasalization (Gibbon et al., 2005). The error in question involves the tongue rising up to an abnormally high position during the production of some vowels, with the result that the tongue makes full contact against the palate (Gibbon, 2004; Gibbon et al., 2005). With the tongue pressed fully against the palate, air is unable to flow out of the mouth in the normal way and instead escapes through the nose. The view that complete contact during vowels results in nasal airflow is supported by Yamashita and Michi (1991). These authors found that during vowels with complete contact, an “airflow examination showed that breath flowed out through the nose while none was detected from the mouth” (Yamashita and Michi, 1991).

The abnormal vowel articulation involving complete tongue palate contact described above has been detected using the instrumental technique of electropalatography (EPG). EPG records the tongue’s contact against the hard palate and has been used extensively to describe articulation errors mostly affecting consonants that occur in cleft palate speech (see Gibbon, 2004, for a review). The position of the tongue in the mouth plays a central role in vowel production, and EPG detects measurable amounts during high front vowels, such as /i/ (as in *seat*) and high back vowels, such as /u/ (as in *boot*) (Hardcastle and Gibbon, 1997; Howard and Heselwood, 2002; McLeod and Singh, 2009). Although EPG does not measure tongue position directly, nevertheless the data provide an indication of its height in the oral region of the vocal tract. Furthermore, the technique is one of the few that is able to record details of lateral bracing and, by inference, the presence of tongue grooving in the oral region of the vocal tract. The technique is therefore well-suited to investigate tongue activity for high vowels and errors affecting these sounds.

Complete tongue palate contact during high vowels was noted as an articulation error in two EPG studies of Japanese cleft palate speech (Yamashita and Michi, 1991; Yamashita et al., 1992). A more recent and larger study investigated the phenomenon further in English-speaking children with cleft palate (Gibbon et al., 2005). Gibbon et al.’s study reported tongue palate contact during vowels of differing heights in 18 school-aged children with articulation disorders associated with cleft palate. The study found that complete contact was relatively frequent, with 39% of the high vowel /i/ produced in this way. Furthermore, when complete contact occurred, it was throughout the duration of the vowel. In contrast, lower vowels, such as /o/ and /a/, were not affected at all by complete contact.

As described above, the articulation error affecting high vowels in Japanese and English cleft palate speech involved complete tongue palate contact, which extended across the lateral and central regions of the hard palate. These contact patterns were unlike those expected for high vowels in typical speech. In typical speakers' production of high vowels, the lateral margins of the tongue make contact against the palate, a phenomenon known as lateral bracing (Stone, 1991). While the sides of the tongue are raised to brace against the palate, the central portion of the tongue is lowered away from the palate. This creates a central 'groove' configuration, which is crucial in allowing air to flow out of the mouth centrally during production of vowels. All vowels in typical English speech require an unobstructed flow of air through the mouth (oral airflow). The consequence of oral obstruction during vowels, as occurs in complete tongue palate contact, is abnormal nasal airflow.

Although tongue palate contact data for vowels is relevant in the assessment of cleft palate speech, there is currently limited normative EPG data available on which to base judgments about error patterns. Some observations and examples of typical EPG patterns for vowels exist in the literature, however. McLeod and Singh (2009) present EPG printouts from an adult Australian speaker producing a range of vowels, as well as corresponding spectrographic and ultrasound images. The EPG printout presented by McLeod and Singh for /i/ is extracted from the word *beat* and shows lateral contact in the palatal and velar region – lateral bracing – and a narrow central groove. The authors acknowledge that the patterns from this speaker may not be representative of the normal population because the patterns showed "more than anticipated tongue palate contact … due to the coarticulatory influence of the /t/" (McLeod and Singh, 2009). Howard and Heselwood (2002) present an example of each of the vowels /i/, /u/ and /ai/ in the words *bee*, *boo* and *buy*. The EPG patterns for /i/ showed contact along the full extent of lateral margins of the palate, and for /u/ the contact was limited to the posterior lateral margins of the palate. The patterns for the diphthong /ai/ showed contact in the posterior lateral region in the latter stages of the vowel.

Some normative vowel data from adult speakers was presented in the Gibbon et al. (2005) study. These authors showed that in terms of amount of contact, the vowels ranked /i/>/I/>/u/>/o/>/a/, with /i/ having the most and /a/ the least contact. Indeed, this ranking held true in both normal and cleft palate speech, although overall the vowels in normal speech had less contact than in cleft palate speech. Unlike the speakers with cleft palate, none of the typical speakers produced any vowels with complete tongue palate contact. A feature of all typical EPG patterns for high vowels reported by Gibbon et al. (2005), McLeod and Singh (2009) and Howard and Heselwood (2002) was lateral bracing and the presence of a central groove.

Although current literature provides some guidance about the types of patterns expected during typical vowels, the data available is limited in both quality and quantity. In terms of quality, the speech material elicited in previous studies such as Gibbon et al.'s was not designed to investigate vowels and as a result was poorly controlled in terms of the phonetic context in which the vowels occurred. Consequently, vowel contact patterns were significantly affected by adjacent consonants. In terms of quantity, the vowels in previous EPG studies were usually produced only once and the number of participants was small. It is desirable to have multiple repetitions of speech material due to intra-speaker variability and to record an adequately sized group of speakers due to inter-speaker variability. In terms of variability in amount of contact, recent studies have shown that although typical speakers produce similar contact patterns for target sounds, some speakers can have up to twice as much contact as others (Cheng et al., 2007; Gibbon, Lee et al., 2007; Gibbon, Yuen et al., 2007; Liker et al., 2007; Liker and Gibbon, 2008).

The current study aimed to provide a more precise description of typical tongue palate contact patterns for vowels than currently exists in order to allow more accurate identification of vowel error patterns in cleft palate speech. The study used EPG to record multiple repetitions of vowels produced by a group of typical adults and the speech material was constructed so that vowel contact patterns would be minimally affected by adjacent consonants.

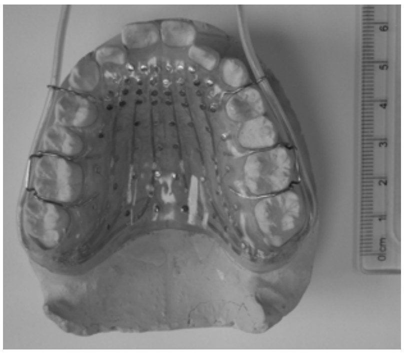
Method

Participants

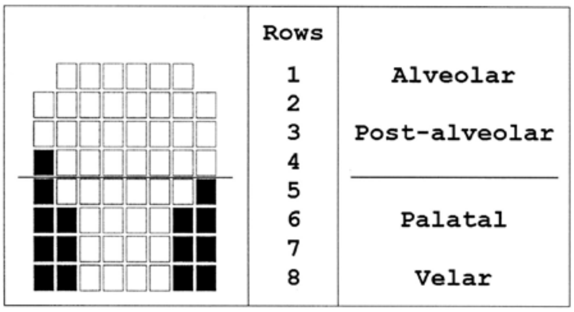
Ten typical adult speakers took part in the study. They ranged in age from 25-64 years, with a mean of 45 years. The participants were faculty staff at Queen Margaret University, Edinburgh, and had a variety of English accents (Southern British Standard for participants 1, 4, 5, 7, and 10; Scottish English for participants 2, 3, 6, 8, and 9). Based on self-report, the participants had no history of speech, language or hearing difficulties. Ethics approval was granted by the Research Ethics Committee of Queen Margaret University College in May, 2006, and written consent was obtained from each participant before data collection. The consent procedure did not inform participants about the purpose of the study, so they were unaware of how their EPG data would be analyzed.

EPG Instrumentation

The Windows® version of the Reading EPG was used in this study (WinEPG™, Articulate Instruments Ltd, 2008), with the EPG sampled at 100 Hz simultaneously with the acoustic signal at 22,050 Hz. In order to record the dynamic tongue palate contact patterns, each speaker had an EPG plate individually constructed to fit against the hard palate (Hardcastle and Gibbon, 1997). The plate contained 62 electrodes, which detected the tongue’s contact and then recorded this contact in a permanent record. Figure 1a shows how the electrodes are arranged, with Row 1 having 6 electrodes, and Rows 2-8 each having eight electrodes. There is a higher density of electrodes in the anterior region of the plate. Figure 1b shows a single EPG palatogram, with row numbers 1-8 indicated as well as information about how the schematic palatograms correspond to phonetic regions of the palate (i.e., alveolar, post-alveolar, palatal, and velar). Tongue palate contact is registered as filled (black) squares and no contact indicated by empty (white) squares. The contact pattern shown in the single palatogram in Figure 1b is an EPG pattern that would be expected during a high vowel such as /i/ in normal speech, with contact in the posterior lateral region (lateral bracing) and a central groove consisting of 4 electrodes that are free of contact in the posterior region of the palate.



(a)



(b)

Figure 1. A Reading EPG plate of a normal speaker placed on top of a plaster impression of the hard palate and teeth is shown in (a). A single EPG frame, showing a typical contact pattern for a high vowel /i/ or /u/ is shown in (b), along with EPG frame row numbers and the phonetic regions of the palate.

Speech Material

Simultaneous EPG and acoustic data were recorded as the participants read out loud a set of short phrases containing six vowel (V) targets (Appendix 1). The vowels investigated in this study were three monophthongs /i/, /u/, /a/ and three diphthongs /ai/, /oi/, /au/. The monophthongs were all long vowels, with /i/ being the vowel of most interest in this study because of its vulnerability to errors in cleft palate speech. The other vowels were included in order to compare amount of contact across vowels of differing heights. The study also recorded diphthongs with high off-glides; these vowels involve tongue movement starting low and ending high.

The vowels under investigation were embedded in a carrier phrase *"a CV papa"*, where the consonant (C) was a bilabial stop /p/ or /b/. The choice of bilabial consonants, which are formed by lip closure, was to minimize the effect of any adjacent consonants on tongue movement for the vowels. Apart from the vowel under investigation, the vowels in the carrier phrase were central or low, again to minimise their effect on the vowels under investigation. Each carrier phrase was repeated ten times, making a total of 600 vowel tokens analysed. The participants were instructed to speak at a natural, conversational rate. In addition, they were instructed to wear the EPG plate for two hours prior to speech recording in order to acclimatize to the presence of an artificial plate inside the mouth when speaking (McLeod and Searl, 2006).

Annotation Points

EPG and acoustic data were displayed on a computer screen using the Articulate Assistant™ software (Articulate Instruments Ltd, 2008). This software is used in conjunction with the WinEPG™ system to make EPG recordings, to display the EPG patterns and to carry out analyses on the data. The vowel segments under investigation were identified on the waveform. The criteria for placing the five annotation points were as follows: the onset (time point 1) and the offset of the vowel (time point 5), plus three equally distanced time intervals through the vowel (time points 2, 3 and 4).

The EPG data from the 5 time points were exported to an Excel file to identify complete contact across the palate and to calculate percent contact profiles across the 5 time points. A formula was used to identify complete contact, which was defined as all electrodes (100%) contacted in any of the 8 rows of the palate, in all EPG frames within the vowel segment.

Figure 2 illustrates how the vowels under investigation were located within the carrier phrase and how the annotations were placed. The example in the figure is the phrase *"a pie papa"*. The waveform for the phrase is shown at the top of the figure, with an orthographic segmentation written above it. Below the waveform is the EPG contact profile. The vowel segment /ai/ is marked on the waveform and contact profile with annotations (shown as vertical lines) at five time points, which are numbered 1-5. The profile reveals that the amount of contact is minimal throughout the first part of the sentence, but starts to increase at annotation point 3 of the vowel (temporal midpoint). From annotation 3, contact rises until it reaches a peak around annotation point 5 (end of vowel). The contact profile in Figure 2 demonstrates that the vowel under investigation (/ai/ in the word *pie* in this example) was the only segment in the sentence registering measurable amounts of tongue palate contact.

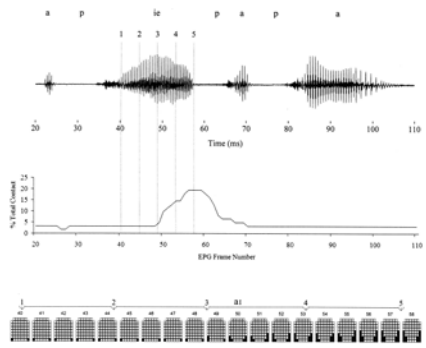


Figure 2. A waveform shows the phrase *"a pie papa"* and below it the EPG contact profile. Annotations for the vowel /ai/ (in *pie*) are marked as vertical lines at five equal time points and numbered 1-5. EPG frames during /ai/ are below the contact profile, with the five time points labelled above the relevant frame.

Figure 2 also shows a full printout of EPG data for the vowel /ai/, located within the time points 1-5. In this example, there were 19 EPG frames numbered 40-58. The frames were sampled at 10 ms intervals, so the duration of this vowel was 190 ms. The five time points are labelled 1-5 above the relevant EPG frame. The EPG printout shows how contact starts to build up at time point 3, corresponding to the increase shown in the contact profile. In Figure 2, none of the EPG frames in the printout have complete contact, as none of the 8 horizontal rows has all electrodes contacted. The full EPG printout provides information that is complementary to the contact profiles in providing details of the location of contact, in this example in the posterior, lateral regions of the palate and a central posterior groove of electrodes that are free of contact.

Results

The results from the EPG data showed no instances of complete contact during any of the 6 vowels investigated. Contact profiles at the 5 annotation points for the monophthongs are in Figure 3. Two observations about the profiles are relevant. First, the vowels /i/ and /u/ had measurable amounts of EPG contact. The vowel /i/ had the most contact (averaging 37% at the peak), and /u/ had less (averaging 21% at the peak). The vowel /a/ registered minimal amounts of contact throughout. Second, the amount of contact was not constant throughout the duration of the vowels. Instead, profiles for /i/ and /u/ show that for both vowels, contact increased gradually from time point 1 (start of the vowel) until it peaked at time point 4 (three quarters of the way through the vowel). After time point 4, contact remained level or dropped off slightly until the end of the vowel at time point 5.

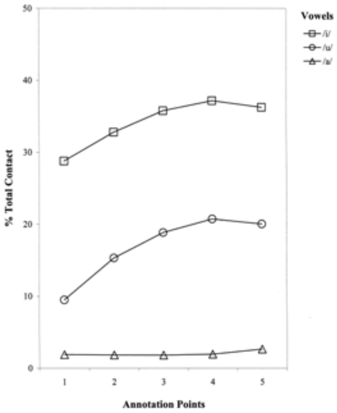


Figure 3. Average percentage contact profiles for /i/, /u/ and /a/ at 5 annotation time points.

The average amount of contact for the vowels produced by each participant at the peak of contact during the vowel (annotation point 4) is presented in Table 1. The values in the table show that speakers varied in the amount of contact produced for /i/; speakers with the highest amount of contact had almost a third more contact than those with the least amount of contact (43% for the highest; 29% for the lowest). For all speakers, /u/ had less contact than /i/, and speakers with the highest amount of contact had almost twice as much as those with the least contact (28% for the highest; 15% for the lowest). Contact for /a/ was minimal, with contact ranging from 0%-4%.

Table 1. Average percentage contact at annotation point 4 for /i/, /u/ and /a/ presented for each participant.

Vowel Participant	/i/	/u/	/a/
1	36.62	23.25	0.00
2	42.10	16.10	0.00
3	43.04	29.50	4.49
4	28.69	20.35	3.36
5	42.88	27.56	2.88
6	38.38	21.80	2.88
7	30.96	14.99	0.64
8	38.56	18.88	0.80
9*	29.66	20.01	2.40
10	40.82	14.98	1.96

* The two outermost electrodes on row 3 of the palate were not working.

Inter-speaker differences in amount of contact are illustrated in Figure 4. This figure shows full EPG printouts for the speaker with the most (Participant 3) and least (Participant 7) amount of contact for monophthongs. These printouts show that for /i/, although the amount of contact varied, the overall contact shape was similar in that both involved posterior lateral contact. In both speakers, the constricted palatal and velar regions had 2-3 electrodes located centrally that remained free of contact, indicating the presence of a central groove.

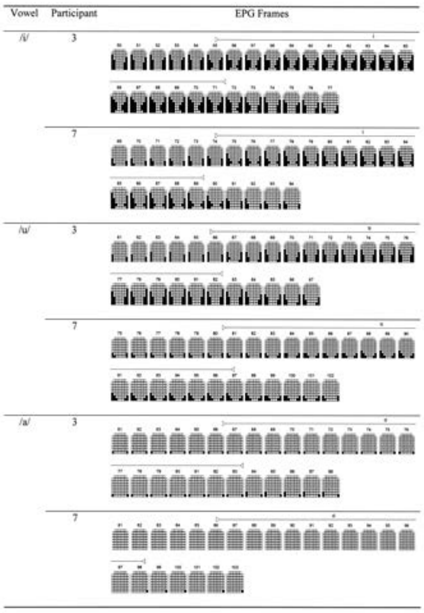


Figure 4. EPG printouts from the speaker with the highest (Participant 3) and the one with the lowest (Participant 7) amount of contact for vowels /i/, /u/, and /a/.

The EPG printouts for /u/ in Figure 4 show a broadly similar pattern to /i/, with contact located in the posterior lateral region of the palate. However, as shown in Figure 3 and Table 1, there is less contact for /u/ compared to /i/ and the central groove is wider for /u/ compared to /i/ (3-5 electrodes wide for /u/; 2-3 for /i/). The printouts for /a/ in Figure 4 show minimal tongue palate contact, but where it does occur, the contact is located once again in the posterior lateral region. A feature of all the EPG patterns for the normal vowels recorded in this study and illustrated in Figure 4, is the presence of centrally located electrodes free of contact. These reflect tongue grooving, which in turn allows air to flow unobstructed through the mouth.

Contact profiles at the 5 annotation time points for the diphthongs /oi/, /ai/ and /au/ are shown in Figure 5. The profiles for /oi/ and /ai/ are similar in that both show minimal contact up until time point 2, when contact increases slightly and then rapidly at time point 3. The profile for /au/ is similar to /ai/ and /oi/ up to time point 3 – the vowel midpoint – but rises less rapidly and peaks at a lower point. Although contact beyond the end of the vowel is not presented, the profile in Figure 2 for /ai/ suggests that contact is at its peak at the end of the vowel. The final comment concerns the amount of contact registered. Although the diphthongs investigated had high vowel off-glides, the amount of contact at their peak was lower than for monophthongs (see Figures 3 and 5). Maximum contact during the monophthong /i/ reached 37%, compared to 22% for /oi/ and 20% for /ai/. Likewise, maximum contact during the monophthong /u/ reached 21%, compared to 12% for /au/.

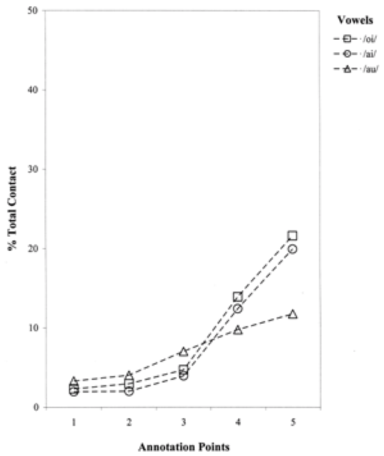


Figure 5. Average percentage contact profiles for /oi/, /ai/ and /au/ at 5 annotation time points.

Discussion

The results of this study show that tongue grooving, as indicated on EPG patterns as centrally located electrodes that are free of contact, is a feature of the normal vowels. A similar observation was found in studies employing other instrumental techniques such as ultrasound and x-ray in vowel production (Stone 1991; Stone and Lundberg, 1996; Stone et al., 1988; Kent and Moll, 1972). This groove configuration is important, as it allows air to flow out of the mouth during vowel production. The main clinical implication is that when complete tongue palate contact occurs during vowels, as reported in cleft palate speech, it can be considered an articulation error. Complete contact suggests that the tongue is raised to the extent that it presses up against the palate, obstructing airflow through the mouth and increasing the likelihood of nasalized vowels. This aligns with the view of Curtis (1970) and Jones (1991) that perceived nasality is related to the ratio of the nasal and oral acoustic impedances. The complete tongue palate contact might have created a very high acoustic impedance to sound transmission into the oral cavity. Hence, if inadequate velopharyngeal closure is present, the sound is more likely to transmit into the nasal cavity due to its relatively lower acoustic impedance (Jones, 1991). EPG would therefore be useful in finding out whether inappropriate complete tongue palate contact has occurred, which might have contributed to excessive nasal resonance in a patient. Clinicians may employ EPG in speech therapy to provide visual feedback to help the patient to achieve adequate tongue palate contact, with the aim of reducing oral impedance and improving oral resonance. This might eventually result in either acceptable oral resonance or less hypernasal quality depending on the velopharyngeal function. This approach is in congruence with the “increase oral activity” method that has been suggested previously (Kummer, 2008).

The normative data provided in this study will be useful to speech-language pathologists who use EPG in their clinical work. In particular, clinicians should be aware that normal speech involves a relatively large amount of contact (30%-40%) during high vowels. The amount could be even greater than this during vowels spoken in contexts where adjacent consonants also involve measurable EPG contact, for example, in words such as *sheet*, *shoot*, *cheese*, *choose*. Regardless of the precise amount of contact, the results of this study and previous reports (Gibbon et al., 2005; Howard and Heselwood, 2002; McLeod and Singh, 2009) show that the main characteristic of EPG patterns during high vowels in normal speech is contact located in the posterior, lateral regions of the palate, combined with a central posterior groove configuration of electrodes that are free of contact. These typical data will be useful when identifying EPG error patterns in cleft palate speech and also when devising appropriate target patterns when using EPG in visual feedback therapy.

The differing contact profiles for the monophthongs and diphthongs warrant brief commentary. The profiles for monophthongs (Figure 3) and diphthongs (Figure 5) are interpreted as reflecting different tongue dynamics involved in the production of these vowels. The sharp increase in contact half way through the diphthongs is interpreted as due to a rapid upwards thrust of the tongue for the off-glide. The tongue makes contact with the palate midway through the vowel and continues to rise throughout the second half of the vowel, reaching a peak at the end of the vowel. Although the diphthongs /oi/ and /ai/ have high off-glides, the EPG data confirm that tongue height for the diphthong off-glides is lower compared to monophthong /i/ (Figures 3 and 5). The same finding is true for /au/ compared to /u/. In contrast, monophthong profiles shown in Figure 3 suggest that, compared to diphthongs, the tongue started in a higher position and moved more gradually upwards until it reached its target position, which it achieved between the midpoint and end of the vowel. The data illustrate the complexity of vowels, demanding that the tongue constantly changes shape as well as requiring it to travel at different speeds and directions towards and away from target positions in order to produce intelligible speech sounds.

The results of this study highlight inter-speaker variability in the overall amount of contact produced for the same target vowel. This finding is consistent with previous studies, which have found that typical speakers vary in the overall amount of contact they produce. For example, Gibbon, Yuen et al. (2007) conducted a study on normal alveolar stops (i.e., /t/, /d/ and /n/) and found that some speakers had more than twice as much contact as other speakers. Studies of typical velars (Liker and Gibbon, 2007), bilabials (Gibbon, Lee et al., 2007), and affricates (Liker et al., 2007) reached a similar conclusion. One explanation for this variation is that amount of contact reflects different hard palate shapes. More specifically, individuals with flatter palates tend to have higher overall amounts of contact than those with more steeply arched palates (Hiki and Itoh, 1986).

There are other possible explanations for the inter-speaker variability shown in this and other studies, however. The contact could reflect speakers' differing long-term jaw and tongue settings, or degree of articulatory effort. The precise relationship between speaker characteristics (e.g., anatomy, articulatory settings, speech style) and EPG data is not known at present. Structural factors are particularly relevant because the hard palates of cleft speakers (at least those with a cleft of the alveolus) tend to be smaller and more irregular in shape than those of normal speakers. Furthermore, abnormal dental conditions as well as malocclusion are frequent in people with cleft palate. A final possible explanation for interspeaker differences in amount of contact in this study was that it was due to differences in accent. For example, it has been stated that vowels /a/ and /u/ are more fronted in Scottish accent when compared to Southern British standard (Giegerich, 1992). In this study, speaker accents were not controlled and it is possible that some speakers had more contact due to higher or more fronted vowels. Despite inter-speaker variations in the amount of contact, it is nevertheless possible to identify certain error patterns. An example is the occurrence of complete tongue palate contact during vowels, which is not a pattern produced in normal speech.

A clinical implication arising from the current study is the importance of selecting carefully the phonetic context when assessing vowels in cleft palate speech. The speech material used in this study was designed to elicit only tongue movements associated with the vowels under investigation. The contact profile in Figure 2 confirmed that this goal was achieved; contact was minimal throughout the sentence except when it was associated with tongue movement during the vowel. In the clinic setting, it may be necessary or desirable to assess accuracy of tongue movements associated solely with vowels in some individuals with cleft palate. An example is where error patterns affecting lingual consonants may be anticipated or carried over into the vowel. The speech material used in this study would be appropriate with appropriate modifications for assessing tongue contact during vowel production.

Acknowledgments

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References

Articulate Instruments Ltd. *Articulate Assistant User Guide*. Version 1.17. *WinEPG Installation and Users Manual*. Revision 1.15. Edinburgh UK: Articulate Instruments Ltd; 2008.
Cheng HY, Murdoch BE, Goozée JV, Scott D. Electropalatographic assessment of tongue-to-palate contact patterns and variability in children, adolescents, and adults. *J Speech Lang Hear Res.* 2007;50:375-392.
Curtis JF. The acoustics of nasalized speech. *Cleft Palate J.* 1970;2:380-396.
Gibbon F. Abnormal patterns of tongue-palate contact in the speech of individuals with cleft palate. *Clin Linguist Phonet.* 2004;18:285-311.
Gibbon F, Lee A, Yuen I. Tongue palate contact during bilabials in normal speech. *Cleft Palate Craniofac J*. 2007;44:87-91.
Gibbon F, Smeaton-Ewins P, Crampin L. Tongue-palate contact during selected vowels in children with cleft palate. *Folia Phoniatr Logop.* 2005;4:181-192.
Gibbon F, Yuen I, Lee A, Adams L. Normal adult speakers’ tongue palate contact patterns for alveolar oral and nasal stops. *Adv Speech Lang Pathol*. 2007;9:82-89.
Giegerich HJ. *English phonology: An introduction*. Cambridge: Cambridge University Press; 1992.
Hardcastle WJ, Gibbon F. Electropalatography and its clinical applications. In: Ball MJ, Code C, eds. *Instrumental Clinical Phonetics.* London: Whurr Publishers; 1997:149-193.
Hiki S, Itoh H. Influence of palate shape on lingual articulation. *Speech Commun.* 1986;5:141-158.
Howard SJ, Heselwood B. The contribution of phonetics to the study of vowel development and disorders. In: Ball MJ, Gibbon FE, eds. *Vowel Disorders*. Woburn: Butterworth Heinemann; 2002:37-82.
Jones DL. Velopharyngeal function and dysfunction. *Clin Commun Disord.* 1991;1:19-25.
Kent RD, Moll KL. Tongue body articulation during vowel and diphthong gestures. *Folia Phoniatr.* 1972;24:278–300.
Kummer AW. *Cleft palate and craniofacial anomalies: Effects on speech and resonance*. New York: Thomson Delmar Learning; 2008.
Lewis KE, Watterson T, Quint T. The effect of vowels on nasalance scores. Cleft Palate Craniofac J. 2000;37:584-589.
Liker M, Gibbon F. Tongue palate contact patterns of velar stops in normal adult English speakers. *Clin Linguist Phon.* 2008;22:137–148.
Liker M, Gibbon F, Wrench A, Horga D. Articulatory characteristics of the occlusion phase of /t/ compared to /t/ in adult speech. *Adv Speech Lang Pathol*. 2007;9:101-108.
McLeod S, Searl J. Adaptation to an electropalatograph palate: Acoustic, impressionistic, and perceptual data. *Am J Speech Lang Pathol*. 2006;15:192-206.
McLeod S, Singh S. *Speech Sounds: A Pictorial Guide to Typical and Atypical Speech*. San Diego: Plural Publishing; 2009.
Moll KL. Speech characteristics of individuals with cleft lip and palate. In: Spriestersbach DC, Sherman D, eds. *Cleft Palate and Communication*. London: Academic Press; 1969:61-118.
Morley ME. *Cleft Palate and Speech.* 7th ed. Edinburgh, Scotland, Churchill Livingstone; 1970.

Peterson-Falzone SJ, Hardin-Jones MA, Karnell MP. *Cleft Palate Speech.* 3rd ed. Mosby: St Louis; 2001.
Spriestersbach DC, Darley FL, Rouse V. Articulation of a group of children with cleft lips and palates. *J Speech Hear Res.* 1956;21:436-445.
Stone M. Toward a model of three-dimensional tongue movement. *J Phon*. 1991;19:309-320.
Stone M, Lundberg A. Three-dimensional tongue surface shapes of English consonants and vowels. *J Acoust Soc Am*. 1996;99:3728-3737.
Stone M, Shawker T, Talbot T, Rich A. Cross-sectional tongue shape during vowels. *J Acoust Soc Am*. 1988;83:1586–1596.
Yamashita Y, Michi K. Misarticulation caused by abnormal lingual-palatal contact in patients with cleft palate with adequate velopharyngeal function. *Cleft Palate Craniofac J.* 1991;28:360-366.
Yamashita Y, Michi K, Imai S, Suzuki N, Yoshida H. Electropalatographic investigation of abnormal lingual-palatal contact patterns in cleft palate patients. *Clin Linguist Phon.* 1992;6:201-217.

Appendix 1. Speech Material.

Target vowels	Sentences
/i/	a p<u>ea</u> papa
/u/	a b<u>oo</u> papa
/a/	a p<u>ah</u> papa
/au/	a P<u>ow</u> papa
/oi/	a b<u>oy</u> papa
/ai/	a p<u>ie</u> papa