CORA Cork Open Research Archive
Cartlann Taighde Oscailte Chorcaí

Title	Producing turbulent speech sounds in the context of cleft palate
Authors	Gibbon, Fiona E.;Lee, Alice S.
Publication date	2010-04
Original Citation	Gibbon, F. and Lee, A. (2010) 'Producing turbulent speech sounds in the context of cleft palate, in Fuchs, S., Toda, M. and Zygis, M. (eds.) Turbulent sounds: an interdisciplinary guide. Germany: De Gruyter, pp. 303-341. ISBN 978-3-11-022658-4
Type of publication	Book chapter
Link to publisher's version	http://www.degruyter.com/view/product/43500
Rights	© Walter de Gruyter GmbH & Co. KG. 10785 Berlin/New York
Download date	2026-11-05 17:36:27
Item downloaded from	https://hdl.handle.net/10468/3031

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Producing turbulent speech sounds in the context of cleft palate

Fiona E. Gibbon and Alice Lee

1. Introduction

Over the past 40 years, a combination of improved surgical technique, multidisciplinary working, and speech therapy has resulted in measurable progress in treating individuals with cleft palate (Kawano et al. 1997). Despite these gains, speech disorders in this group are a serious problem – it is estimated that between 50–90% of individuals with cleft palate require episodes of speech therapy (Albery and Grunwell 1993; Peterson-Falzone 1990a; Witzel 1991). If a speech disorder persists past the preschool years, it can adversely affect individuals' social communication and emotional wellbeing as well as their educational and ultimately their employment prospects.

This chapter focuses on abnormal articulations that can develop when individuals have structural (anatomical) abnormalities that interfere with their ability to create normal air turbulence in the oral cavity. Abnormal articulations that have a constriction located in the oral region are illustrated using data recorded from the instrumental technique of electropalatography (EPG). Studies that have used other instruments to investigate abnormal articulations located in the pharyngeal and laryngeal regions are also discussed. In preparing the ground for these discussions, there follows some introductory remarks for readers who may be unfamiliar with cleft palate and to explain the pivotal role of speech turbulence in the development of abnormal articulations.

1.1. Speech turbulence

Moin and Kim (1997: 62) define turbulence as "composed of eddies: patches of zigzagging, often swirling fluid, moving randomly around and about the overall direction of motion". They go on to say that technically, the chaotic state of fluid motion arises when the speed of the fluid exceeds a specific threshold. Thus, in order to create a turbulent flow of air for

speech, under normal circumstances speakers must constrict the articulators to a greater or lesser extent and build up sufficient air pressure behind the constriction to create plosion or friction. Sounds produced this way, namely plosives, fricatives, and affricates, are known collectively as obstruent sounds and all involve creating turbulent airflow. The acoustic characteristics of turbulence in speech sounds are complex and manifold, and are determined by a combination of factors, such as the intraoral air pressure, oral airflow rate, the location and shape of the constriction through which the air passes and so on (e.g., Hixon, 1966; Stevens, 1998).

1.2. Cleft palate

Cleft palate is a congenital malformation of the hard or soft palate, or both, which under normal circumstances is repaired surgically during the first 12–18 months of life. Most developed countries have well organized and sophisticated health care regimes for the management of individuals born with cleft palate. A cleft palate is usually identified around the time of birth, although these days it can be identified in utero using ultrasound technology. Specialist multidisciplinary teams are responsible for developing and coordinating individualized treatment plans to ensure that each person's complex medical, psychological, and social needs are met from birth to adulthood. The team consists of a surgeon, an orthodontist, and a speech and language therapist, with additional specialist input from otolaryngology, audiology, dentistry, paediatrics, genetics, psychology, and social work. Following primary surgery as infants, many undergo further surgery during childhood and adolescence in order to provide the best possible vocal tract structures for normal speech, hearing, and eating.

1.3. Early speech development in infants with cleft palate

The timing of the primary palatal repair at around 12–18 months means that babies born with cleft palate are, at least during the pre-speech period, "obligated to engage in vocal practice without the normal division between the oral and nasal cavities provided by the hard and soft palate and, in many cases, the absence of normal articulatory contacts in the anterior portion of the hard palate" (Peterson-Falzone, Trost-Cardamone, and Karnell 2006: 5). These anatomical constraints, together with frequently occurring middle

ear infection and accompanying conductive hearing loss, can have detrimental effects on babies' vocalization development. Studies have shown that early pre-surgery vocalizations in babies with cleft palate are restricted in the types of sounds they produce. Most noticeably they produce a smaller number of consonant types with fewer oral plosives, and fricatives than typically developing babies (Chapman 1991; Chapman et al. 2001; Grunwell and Russell 1988; Hutters, Bau, and Brøndsted 2001; O'Gara and Logemann 1988). In terms of place of articulation, they avoid the hard palate as a place of articulation with the result that they tend not to produce sounds with alveolar or postalveolar placement (Peterson-Falzone, Trost-Cardamone, and Karnell 2006). Not surprisingly, babies with cleft palate produce more sounds that do not require velopharyngeal closure (e.g. nasals, glottal stops, glottal fricatives) during babbling than babies with intact velopharyngeal mechanisms.

Patterns of sound usage during babbling are relevant because during this period, children are developing their phonological systems, and previous studies on normal speech acquisition have shown that the sounds used frequently in babbling are the ones that appear in early words (Stoel-Gammon 1985; Vihman et al. 1985). As a result, a limited babbling inventory can adversely affect early phonological development and result in an equally reduced phonetic inventory during the first word stage at the 12–18 month period, even if primary palatal surgery has been successful.

1.4. Velopharyngeal dysfunction and oronasal fistulae

Structural defects, such as velopharyngeal dysfunction (VPD) and oronasal fistulae, can persist after primary surgery. These defects are potential hazards to an individual's ability to create and control turbulent airflow for speech sounds made in the oral cavity. A properly functioning velopharyngeal mechanism is a prerequisite in achieving normal oral-nasal resonance and adequate intraoral pressure for speech. VPD, on the other hand, results in an inability of the velopharyngeal structures to separate the nasal cavity adequately from the oral cavity during speech. The perceptual results of VPD are hypernasality and/or nasal emission due to excessive amounts of airflow escaping into the nasal cavity. An oronasal fistula is an opening between the oral and nasal cavity and, like VPD, can result in air escaping into the nose. The incidence of VPD after primary cleft palate repair has been found to range from 25% to 44%, depending on the cleft

type and surgical procedures (Krause, Tharp, and Morris 1976; see also Phua and de Chalain 2008, for a detailed review). The incidence of oronasal fistulae has been found to vary even more widely, from 0% to 34% (Cohen et al. 1991; Phua and de Chalain 2008) depending on a number of factors such as the extent of clefting and the type of repair. Due to air leakage into the nose, these structural abnormalities can make it difficult, or even impossible, for some speakers to build up the necessary oral pressure to produce obstruent sounds.

1.5. Compensatory errors affecting obstruent sounds

An appreciation of the concept of compensatory errors assists in understanding the nature of articulation errors, particularly errors affecting obstruent sounds that are produced by individuals with cleft palate. Compensatory errors are speech behaviours that are interpreted as being due to abnormal learning. Speakers are thought to adopt compensatory articulations in order to reduce the perceptual or acoustic consequences of a structural deficit, such as an oronasal fistula or VPD. Warren (1986), however, views compensatory articulations as arising more from a need to maintain a stable aerodynamic environment for speech production rather than achieving a perceptual or acoustic goal (see Netsell 1990). Regardless of how they arise, once learned, these abnormal learned patterns can persist due to habituation (Peterson-Falzone, Hardin-Jones, and Karnell 2001) even after the structural abnormality has been corrected (e.g. following surgery).

As described in the previous section, structural abnormalities such as VPD and oronasal fistulae can make producing obstruents in the oral cavity problematic due to air leakage and a difficulty building up sufficient pressure to produce turbulence in this part of the vocal tract. Nevertheless, it is still possible for individuals to compensate for this difficulty by producing obstruents at different locations in the vocal tract instead. By making an articulatory constriction “upstream” of the structural defect, speakers can circumvent air leakage and its consequences for obstruent sound production. In other words, individuals with VPD can still produce these sounds below the level of the velopharyngeal structures, for example, in the pharyngeal and laryngeal regions of the vocal tract. Similarly, an individual with a large oronasal fistula in the hard palate can circumvent air leakage by producing obstruents in the velar and uvular regions (provided

there is no VPD) as well as in the pharyngeal and laryngeal regions. The shift of place of articulation upstream of the structural defect just described results in abnormally retracted place of articulation. A final possibility is that the speaker uses the tongue body to aid velopharyngeal closure, a phenomenon referred to as "lingual assistance" (Brooks, Shelton, and Youngstrom 1965; Trost 1981). In this remarkable maneuver, the tongue body moves upwards and backwards to assist velopharyngeal closure with the result that placement is also retracted. Not surprisingly, retracted place of articulation for obstruents is one of the most characteristic and pervasive features of cleft palate speech reported in the literature (Morley 1970; Trost 1981; Trost-Cardamone 1997; Wyatt et al. 1996).

Although speech disorders are frequent in individuals with cleft palate, studies conducted in the US have shown relatively low rates of compensatory errors. Peterson-Falzone (1990a) investigated a group of 240 children with cleft palate aged 4–11 years and found that 22% had compensatory errors. Dalston (1992) found a somewhat higher prevalence rate of 28%, and the latest study by Hardin-Jones and Jones (2005) reported a prevalence of 25% in 212 preschoolers with cleft palate. A recent study of 42 school children and adolescents with repaired cleft palate in Greece showed a prevalence of 28.5% for compensatory articulations (Paliobei, Psifidis, and Anagnostopoulos 2005). This study on Greek-speaking children seems to support the assumption that lower prevalence rates are associated with younger age of palatal surgery.

Peterson-Falzone (1989) used perceptual analysis to investigate the frequency of different types of compensatory articulations in a group of 112 individuals with repaired cleft palate. Consistent with the view that compensatory errors involve predominantly retracted placement, her study found that frequency varied, and reported the following (from most to least frequent): glottal stops; middorsum palatal stops; pharyngeal fricatives; velar plosives; pharyngeal affricates; palatal fricatives; pharyngeal stops; and velar fricatives (Peterson-Falzone 1989). Hardin-Jones and Jones (2005) reported a similar trend, with glottal articulations as the most prevalent errors, followed by middorsum palatal stops and pharyngeal productions.

1.6. Dental and occlusion abnormalities

Dental and occlusal abnormalities, which are common in individuals born with cleft palate, affect dentition and the way in which the upper and lower teeth meet when the jaws bite together. Dental and occlusion abnormalities do not cause a problem of air leakage into the nasal cavity in the same way as VPD or oronasal fistulae, but they can cause sounds made in the oral cavity to be distorted. Dental and occlusal abnormalities can therefore have a direct effect on articulation and the acoustic characteristics of obstruent sounds. For example, speech problems are likely to occur where a dental or occlusal problem significantly reduces intraoral area and consequently the space within which the tongue can move. Such a restriction can occur when individuals have small/narrow hard palates or when they have a Class III malocclusion (Peterson-Falzone 1990b), which occurs when the maxillary molars are posterior to mandibular molars when the jaws bite together. Avoiding placement in the alveolar region may be exacerbated by diminished sensation in this area due to scarring following surgery. Similarly, deviated anterior teeth that are rotated or ectopic may also adversely affect the tongue's ability to make alveolar placement or to form the anterior groove necessary for normal sibilant sound production.

In terms of effects on speech, Albery and Grunwell (1993) found that malocclusions can cause difficulties in forming a seal between the sides of the tongue and the hard palate. A seal is necessary to produce a normal central airstream and to prevent loss of air laterally into the buccal cavities for sounds such as /s/, /z/, /ʃ/, /ʒ/, /tʃ/, and /dʒ/. Lateral escape of air in these circumstances can lead to distorted, usually lateralized, productions of alveolar obstruent sounds. Class III malocclusions may also cause the tongue tip to protrude between the upper and lower teeth leading to interdental productions of alveolar plosives and a "lisp" produced for sibilant sounds (Vallino and Tompson 1993). Another distortion that may arise in speakers with severe malocclusion is a labio-dental substitution, which may replace bilabial targets because the malocclusion prevents the lips approximating in the normal way (Peterson-Falzone, Hardin-Jones, and Karnell 2001).

2. Abnormal articulations located in the oral region

The sections that follow give examples of abnormal articulations produced with constriction in the oral region of the vocal tract. The examples are from speakers with repaired cleft palate and they illustrate errors described in the previous sections. As already mentioned, these errors primarily affect obstruent sounds located in the oral region, which makes electropalatography (EPG) an ideal instrument for recording the dynamic details of the tongue-palate contact associated with these abnormal articulations.

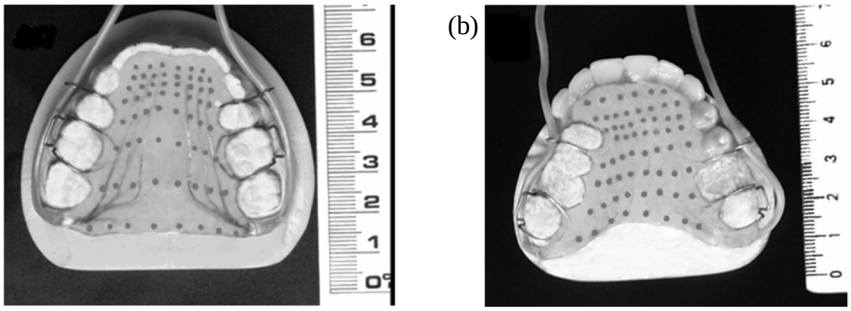
2.1. Electropalatography (EPG)

EPG is an instrumental procedure that records details of the location and timing of the tongue's contact with the hard palate during speech (Hardcastle and Gibbon 1997; Hardcastle, Gibbon, and Jones 1991). Two commercially available versions have dominated EPG research in the study of cleft palate speech: a British system – the EPG3 system developed at the University of Reading – has been used in the majority of cleft palate studies conducted by researchers in the UK and Hong Kong. A new Windows® version of the Reading EPG has recently been developed at Queen Margaret University, Edinburgh, UK (Scobbie, Wood, and Wrench 2004). The Rion EPG (Fujimura, Tatsumi, and Kagaya 1973; Hiki and Itoh 1986) is used in studies reporting Japanese cleft palate speech.

A component of all EPG systems is a custom-made artificial plate moulded to fit the speaker's hard palate. Figure 1 shows a Reading plate for a normal speaker and a similarly aged adult with a cleft palate. Embedded in the artificial plate are electrodes exposed to the lingual surface. The Reading and Rion plates are made from a relatively rigid acrylic, and are held in place by metal clasps that fit over the upper teeth. The Reading plates have 62 electrodes placed according to identifiable anatomical landmarks (Hardcastle, Gibbon, and Jones 1991). The electrodes are arranged in eight horizontal rows, with eight electrodes in every row except the most anterior, which has six. The most posterior row of electrodes on the Reading plates is located on the junction between the hard and soft palates. Figure 1c shows a single EPG frame, which is a typical contact pattern of alveolar stops /t/, /d/, and /n/,[1] divided into different phonetic

regions (alveolar, postalveolar, palatal, and velar), and information on the part of the tongue that is assumed to make contact with these regions.

Of relevance to this chapter is that EPG systems that use Reading plates register characteristic patterns in normal speakers for all English lingual obstruents /t/, /d/, /k/, /g/, /s/, /z/, /ʃ/, /ʒ/, /tʃ/, and /dʒ/. Articulations that have their primary constriction either further forward than the most anterior row of electrodes (e.g. dentals or labials) or further back than the most posterior row of electrodes (e.g. velars in the context of open vowels, uvular, pharyngeal and glottal sounds) have minimal EPG contact patterns. Some EPG contact may be present during these articulations, however, due to the influence of surrounding vowels (Gibbon, Lee, and Yuen 2007).



(b)

(c)

Normal	Row		
0 0 0 0 0 0	1	Alveolar	Anterior (tongue tip/blade)
0 0 0 . . 0 0 0	2		
0 . . . . . 0 0	3	Post-alveolar	
0 0	4		
0 0	5		
0 0	6	Palatal	Posterior (tongue dorsum)
0 0	7		
0 0	8	Velar	

Figure 1. A Reading plate of (a) a normal speaker, (b) a similarly aged adult with a cleft palate, and (c) a single EPG frame, showing a typical contact pattern of alveolar stops /t/, d/, and /n/; with EPG frame row numbers 1 through 8 indicated, as are the phonetic regions of the palate (alveolar, postalveolar, palatal, and velar), and the part of the tongue assumed to make contact with these regions (adapted with permission from Gibbon and Crampin, 2001).

There have been recent advances in the design of EPG plate – the Articulate EPG plate, which has a similar design to the Reading plate and is compatible with the Reading EPG systems, has the first row of the electrodes advanced by 1 mm for capturing linguo-dental articulation and the last row placed straight across the soft palate, with the midsagittal electrodes about 7-12 mm behind the border of the hard and soft palate (Wrench 2007).

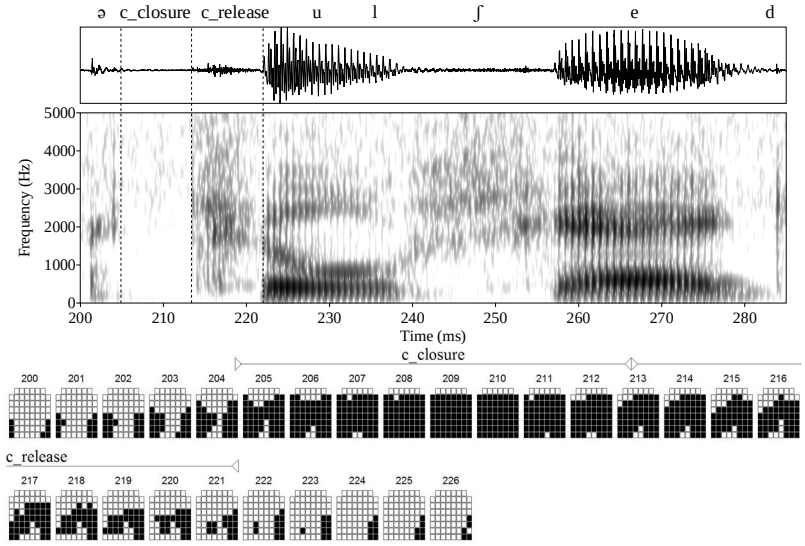
2.2. Middorsum palatal stops

The middorsum palatal stop is one of the most frequently occurring types of compensatory articulations. Trost (1981) originally described [c, ɟ] as substitutions used to replace /t/, /d/, /k/, and /g/. Note that Trost-Cardamone and colleagues use a different set of symbols for transcribing compensatory articulations (see for example, Peterson-Falzone, Trost-Cardamone, and Karnell 2006). Middorsum palatal stops are made in the approximate place of the glide /j/ with midpalatal lingual contact produced with the tongue dorsum raised and the tongue tip down. Trost (1981: 196) states that "perceptually, the phoneme boundaries between /t/ and /k/ or between /d/ and /g/ are lost". Although in middorsum palatal stops /t/ and /d/ targets are retracted from alveolar to palatal placement, /k/ and /g/ targets show the opposite trend as they are fronted from velar to palatal placement.

Palatal stops have been described using EPG in English, Japanese and Cantonese speakers with cleft palate (Gibbon and Crampin 2001; Whitehill et al. 1995; Yamashita et al. 1992). Yamashita et al. (1992) found that about three quarters of 53 Japanese speakers with cleft palate aged 4–20 years produced these abnormal articulations. The EPG patterns for these palatal misarticulations had either contact across the whole surface of the palate or contact that is confined to the posterior region of the palate.

Gibbon and Crampin (2001) used EPG data recorded from an adult with cleft palate who produced middorsum palatal stops, which were typical in the sense that listeners could not distinguish between alveolar and velar targets, with the result that the phoneme boundary between these classes of sounds was lost (Trost 1981). However, this speaker articulated alveolar targets in a subtly different way from velar plosives, a finding that was not predicted from a transcription-based analysis. Figure 2 illustrates this finding and shows EPG patterns for this speaker's production of a /t/ and a /k/, which were both transcribed as [c], with the same targets produced by a normal speaker for comparison in Figure 3.

(a) /t/ → [c] in “a toolshed” produced by an adult male with cleft palate.



(b) /k/ → [c] in “a kettle” produced by an adult male with cleft palate.

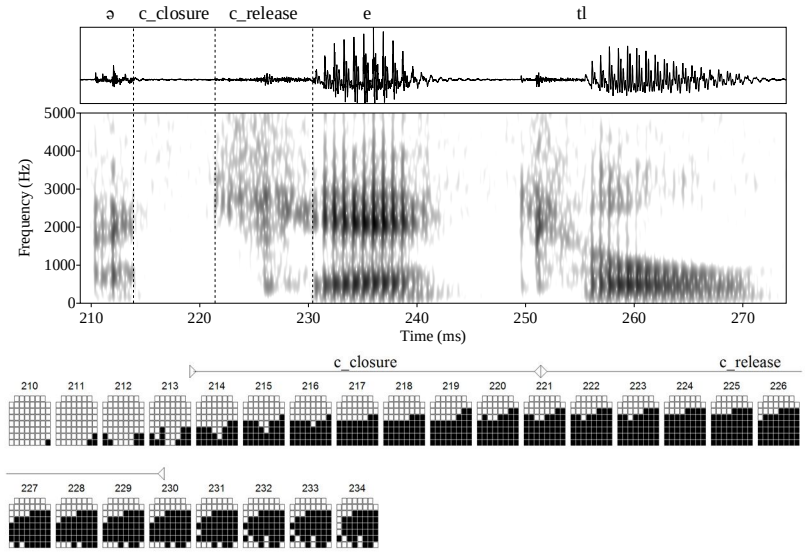
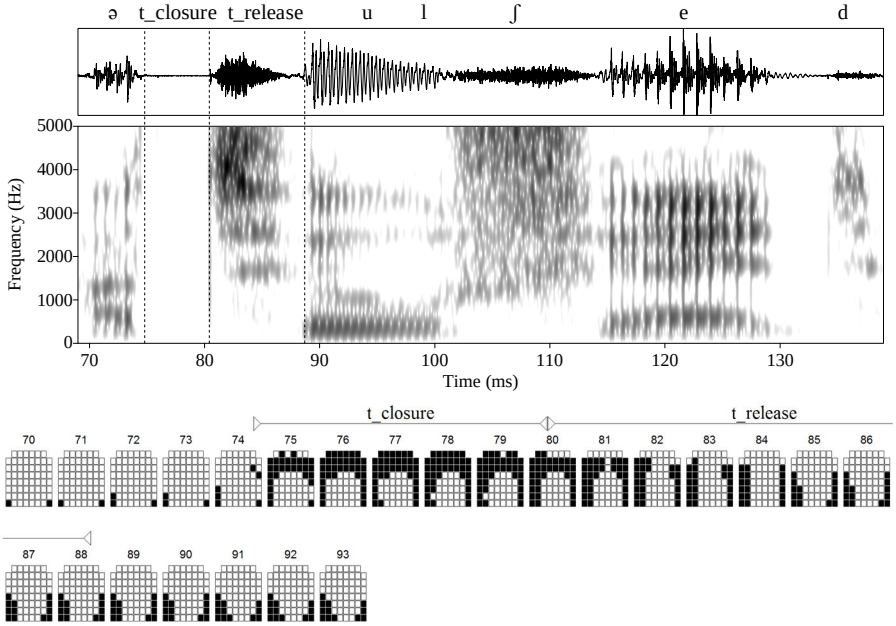


Figure 2. EPG data illustrating middorsum palatal stops used for /t/ and /k/ targets. Simultaneous acoustic and EPG data are shown of two phrases (a) “a toolshed” and (b) “a kettle”, which were realized as middorsum palatal stops and recorded from a 36-year-old man with repaired cleft palate.

(a) /t/ → [t] in “a toolshed” produced by adult male with normal speech.



(b) /k/ → [k] in “a kettle” produced by adult male with normal speech.

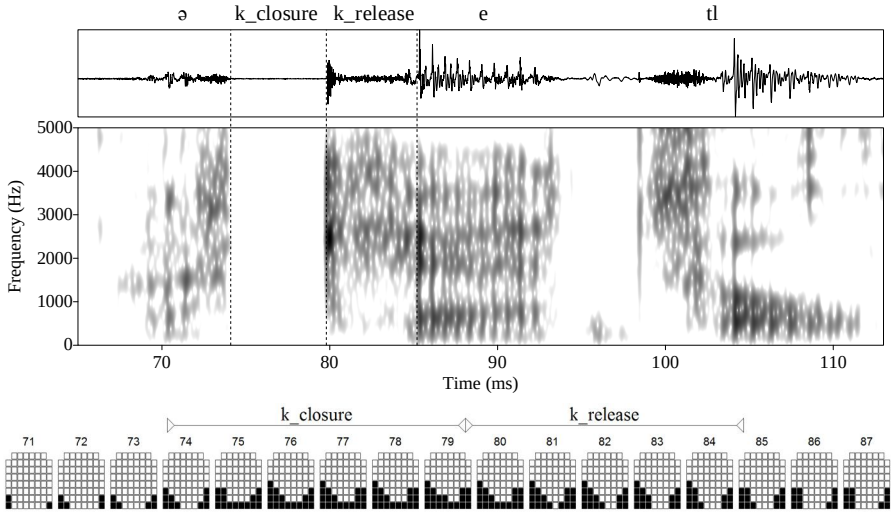


Figure 3. EPG printouts of normal patterns for (a) /t/ in “a toolshed” and (b) /k/ in “a kettle”.

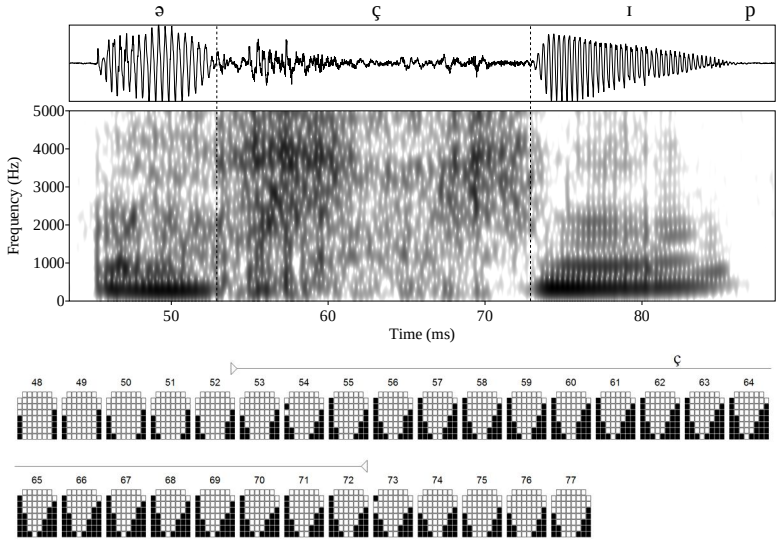
The EPG patterns for the speaker in Figure 2 show that at the onset of closure, tongue placement approximates the normal pattern. Following onset, the EPG patterns during closure are distorted, with a high amount of contact compared to a normal speaker. Although both /t/ and /k/ involved increased contact, nevertheless /t/ has more contact compared to /k/ indicating an articulatory difference between these sound classes. So, although perceptual analysis showed that alveolar and velar targets were middorsum palatal stops, the EPG data revealed that this speaker produced consistent articulatory differences between these targets. (See Gibbon and Crampin 2001, for details of this case and the clinical implications of producing subtle articulatory differences between perceptually neutralized sound contrasts.)

2.3. Palatal/velar fricatives and affricates

Perceptual and EPG studies have shown that palatal and velar fricatives and affricates usually occur as substitutions for alveolar and postalveolar fricatives and affricates (Howard 1998; Howard and Pickstone 1995; Michi et al. 1990; Trost 1981; Yamashita et al. 1992). Palatal and velar fricatives are produced by the tongue dorsum forming a constriction in the posterior region of the hard palate or on the soft palate. Yamashita et al. (1992) found in an EPG study that 25% of Japanese alveolar and palatal fricatives involved retracted placement. Howard and Pickstone (1995) described contact patterns produced by a 6-year-old girl with a repaired cleft of the hard and soft palate. EPG contact patterns for targets /s/, /z/, /ʃ/, and /ʒ/ produced by this child were transcribed as palatal fricatives, and typically involved retracted placement, a fairly broad central groove, and a wide band of side contact from postalveolar to the front of the velar region.

Figure 4a shows an example of a palatal fricative produced by a 9-year-old girl with cleft palate for the alveolar fricative /s/, and below is the same target produced by a normal speaker. The patterns produced by the child with cleft palate show an “inverted” pattern compared to the normal, with a narrow, central groove located in the posterior rather than the normal alveolar region of the palate. Unlike the speaker described by Howard and Pickstone (1995), the patterns in Figure 4 show that this speaker produced a narrow, rather than a broad, posterior central groove configuration.

(a) /s/ → [ç] in “a sip” produced by a girl with cleft palate.



(b) /s/ → [s] in “a sip” produced by a normal speaker.

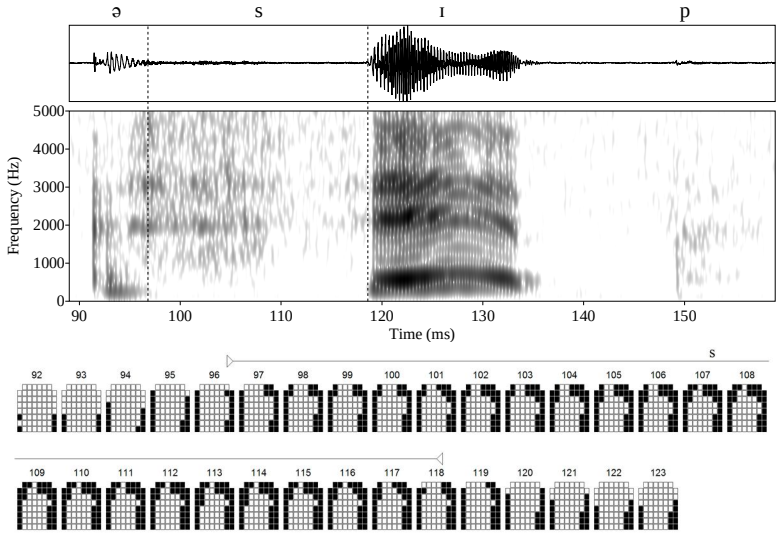
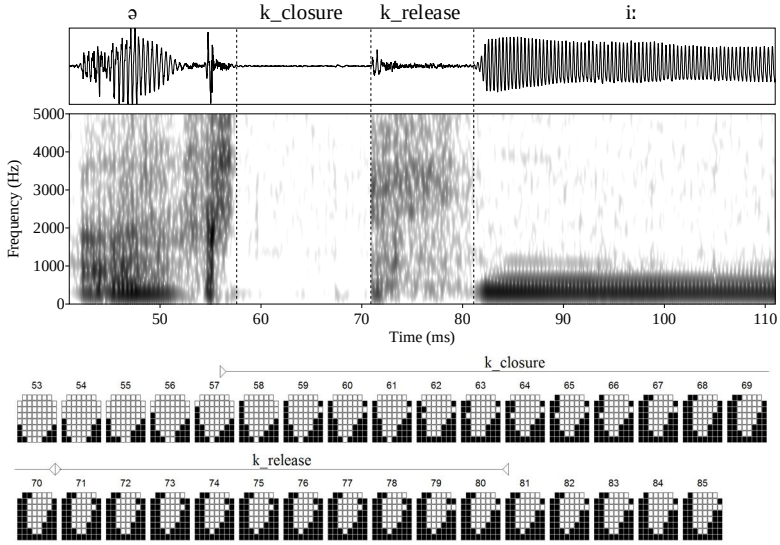


Figure 4. EPG data illustrating a palatal fricative used as a substitution for /s/. The EPG printouts in (a) show a palatal fricative for the /s/ in the phrase “a sip” produced by a 9-year-old girl with repaired cleft palate. A normal pattern for /s/ in the same phrase is shown in (b).

(a) /t/ → [k] in "a team" produced by a girl with cleft palate.



(b) /t/ → [t] in "a team" produced by a normal speaker.

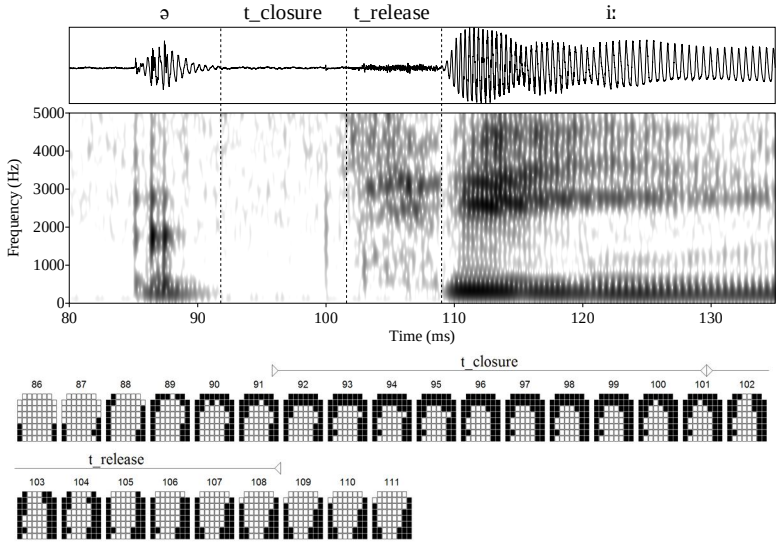


Figure 5. EPG data illustrating a velar plosive produced as a substitution for /t/. The EPG printouts in (a) show a velar plosive for the /t/ in the phrase "a team" produced by a 9-year-old girl with repaired cleft palate. A normal pattern for /t/ in the same phrase is shown in (b).

2.4. Velar plosives

Velar plosives may occur as substitutions for alveolar plosives, and sometimes even for bilabial plosives. Velar plosives involve the tongue dorsum making closure in the region of the junction between the hard and soft palates. Retraction to velar placement can be seen clearly on EPG traces, and has been reported in previous studies of English (Gibbon and Crampin 2001; Gibbon and Hardcastle 1989; Hardcastle, Morgan Barry, and Nunn 1989), Japanese (Yamashita et al. 1992), and Cantonese (Whitehill et al. 1995; Whitehill, Stokes, and Man 1996) speakers with cleft palate. Figure 5a shows a retracted placement from alveolar region to velar region for the target /t/, observed in a girl with cleft palate, which contrasts to the normal pattern illustrated in Figure 5b.

2.5. Lateral fricatives and affricates

Lateral fricatives and affricates usually occur as substitutions for sibilant targets /s/, /z/, /ʃ/, /ʒ/, /tʃ/, /dʒ/ (Gibbon 2004). EPG patterns for lateral fricatives often have increased contact, but do not have an anterior central groove that normal speakers have for these sounds. Suzuki et al. (1981) defined lateral misarticulation as involving the tongue making complete contact across the palate (i.e. there is no evidence of tongue grooving), and lateral release of air (i.e. air directed out of the occluded dental arch posterior to the molar teeth). Likewise, lateral affricates usually involve complete articulatory closure that extends throughout the stop and fricative phases of the affricate. Where complete closure affects sibilant targets there is evidence from the acoustic signal and from perceptual analysis of friction, but the EPG patterns show complete constriction. With complete constriction across the palate, the possibility of a normal central flow of air through an anterior groove is reduced, and the likely escape of air is around the lateral margins of the tongue producing lateral friction.

Figure 6 shows EPG patterns from a girl with a cleft palate producing a target /s/ in the phrase “a sip”, transcribed as a lateral fricative [ɬ] (see Figure 4b for a normal speaker’s production of /s/ in “a sip”). Unlike a normal speaker’s production of /s/, this speaker does not produce an anterior groove configuration combined with lateral contact. Instead, there is complete contact across the palate in the alveolar/postalveolar region, and incomplete lateral contact on the left side. It is likely that the air is

escaping out of the left side into the buccal cavity due to incomplete lateral seal on this side, but this information is inferred from the EPG patterns, and further diagnostic tests would be needed to confirm this.

The EPG configurations involved in speech sound distortions referred to as lateral fricatives, vary between speakers. A study by Yamashita et al. (1992) showed that only a minority of lateral misarticulations involved alveolar contact, such as illustrated in Figure 6. Instead, they found a significant proportion of lateral misarticulations involved contact in the posterior region (i.e. retracted placement) but that the overwhelming majority (68%) involved contact across the whole length of the palate. Lateral fricatives are almost always associated with complete contact across the palate, however.

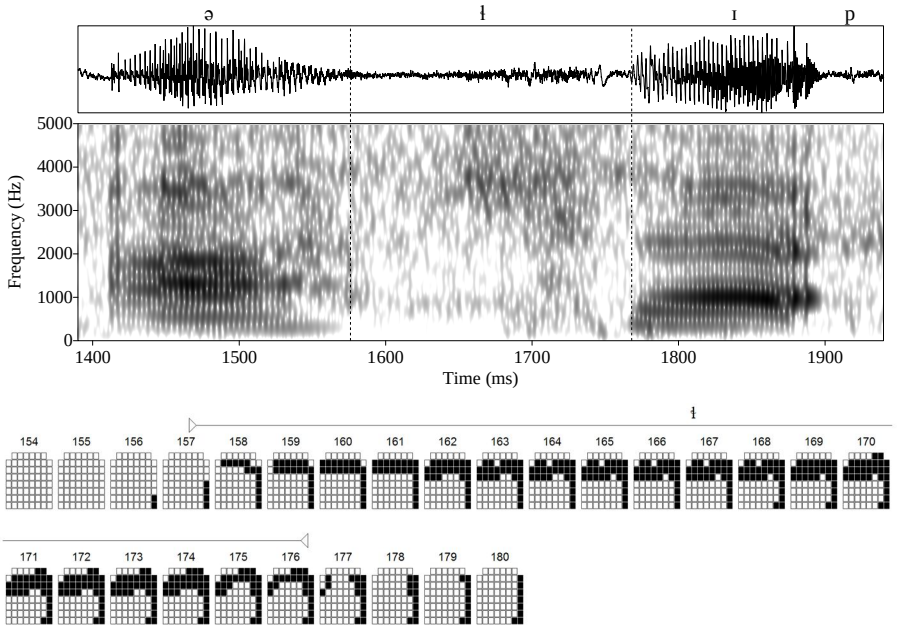


Figure 6. EPG data illustrating a lateral fricative used as a substitution for /s/ in the phrase “a sip” produced by a 12-year-old girl with cleft palate.

2.6. Lateral release of lingual plosives

Although lateral fricatives produced as substitutions have been described frequently in the literature, a less studied characteristic of cleft palate speech is lateral release as a secondary articulatory feature of alveolar and velar plosives (Albery 1991). The lack of research is surprising becauselateral release degrades the acoustic cues that listeners use to identify primary place of articulation. Lateral release is therefore likely to have a detrimental effect on speech intelligibility because it leads to abnormal transitional placement cues. Of relevance here is that normal speakers can have lateral release of /t/ in words such as "bottle", where a lateral /l/ follows a stop (Ball 1993). However, abnormal lateral release occurs in speakers who have this as a general feature of their speech, regardless of the phonetic context.

Gibbon and Crampin's (2001) study of an adult male who produced middorsum palatal stops showed that he had complete tongue palate contact occurring simultaneously with lateral release (see Figure 2a). Gibbon and Crampin showed that articulatory release of the tongue constriction in the central region of the palate for /t/ and /k/ targets was not closely timed with the acoustic plosive burst, as occurs in normal speakers. On average the first third of the aspiration period for their speaker's production of /t/ and /k/ involved lateral escape of air, while the remaining period of aspiration involved a central airstream (Gibbon and Crampin 2001). The timing of articulatory release for /t/ and /k/ was variable, which is consistent with other studies (e.g. Wada et al. 1970) that have reported increased variability in articulatory release in cleft speakers with articulation disorders.

2.7. Double articulations

Abnormal double articulations have been identified in many studies of cleft palate speech (Grunwell 1993; McWilliams, Morris, and Shelton 1990; Morley 1970; Sell, Harding, and Grunwell 1994; Stengelhofen 1989; Trost 1981). Double articulations, which Trost (1981: 200) termed coarticulations or coproductions, involve "one manner of production with simultaneous valving at two places of production". In many standard accounts of cleft palate speech, double articulations are described as involving glottal or pharyngeal articulations, which are usually combined with a second constriction in the oral region. Trost-Cardamone (1990: 233) goes so far as

to state that "only the glottal stop and pharyngeal fricative occur as coarticulations". To explain this statement further, Trost-Cardamone (1990: 233) says that during glottal and pharyngeal constriction, "the tongue is more free to make simultaneous and (more) anterior articulatory contacts".

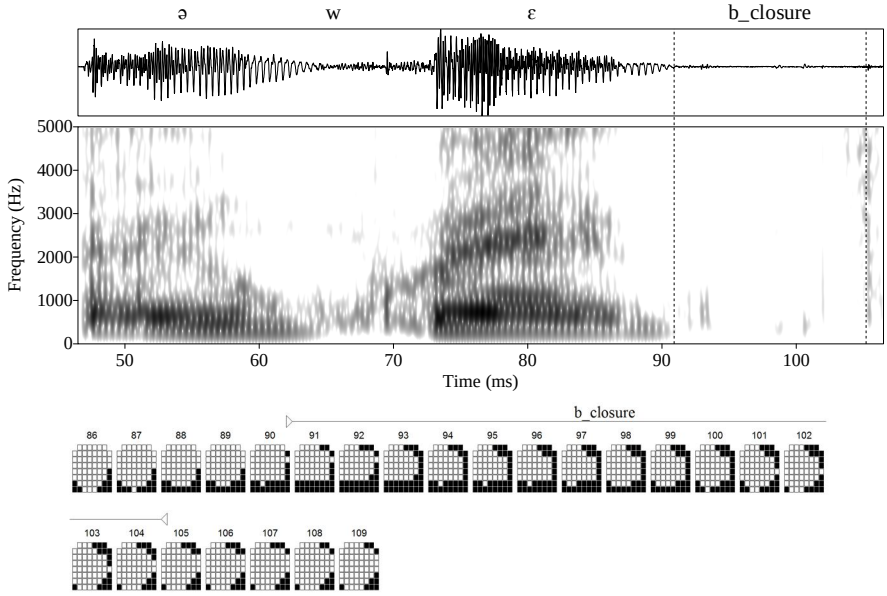
Evidence from EPG studies illustrated in the next sections show that a variety of other types of double articulations can occur. For example, it is possible to have tongue and lip closure occurring simultaneously, resulting in bilabial lingual double articulations. It is also possible to have tongue body and tongue tip/blade double articulations resulting in alveolar-velar double articulations. In other words, the lips, tongue tip/blade, and tongue body are free to make simultaneous closures with each other, with the possibility that a wider variety of double articulations can occur than was previously thought.

2.7.1. Bilabial-velar double articulations

Bilabial-velar double articulation [p͡k] and [b͡g] are double articulations that involve bilabial closure occurring simultaneously with the tongue body making contact against the palate in the velar region. Several case studies have used EPG to reveal these types of double articulations in English speaking children with cleft palate. Gibbon and Hardcastle (1989) first described bilabial-velar double articulations in a case study of a 13-year-old boy with cleft palate. His EPG patterns showed consistent posterior lingual contact occurring throughout the closure period for consonants /p/, /b/, and /m/. Dent, Gibbon and Hardcastle (1992) described a similar case of a 9-year-old boy whose EPG data showed complete contact across the palate in the velar region for labial targets /p/ and /b/. These double articulations are relatively rare, however, with a study finding that just one out of 27 speakers with speech disorders associated with cleft palate produced them (Gibbon and Crampin 2002).

Figure 7a is an example of a bilabial-velar double articulation produced by a 9-year-old boy with a cleft palate. The target /b/ is in word-final position in the word "web". Figure 7b shows the same word produced by a typically developing child of a similar age (see also Gibbon, Lee and Yuen, 2007). The typically developing child shows some contact in the posterior lateral region of the palate, which is normal in the context of bilabial following an /ɛ/ vowel (as occurs in "web"). In contrast, the child with a cleft palate shows complete closure across the palate in the velar region,

(a) /b/ → [b͡g] in a 9-year-old with cleft palate.



(b) /b/ → [b] in a 12-year-old normal speaker.

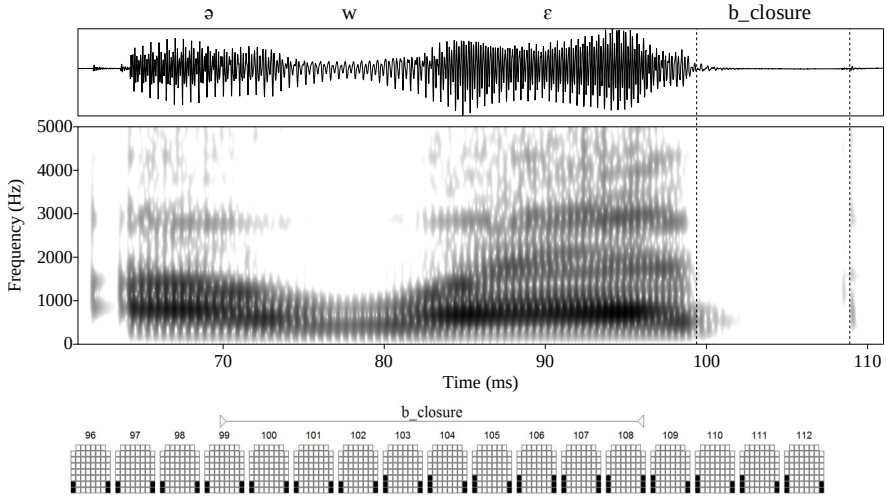


Figure 7. EPG data illustrating bilabial velar double articulation. The EPG printouts in (a) show a bilabial-velar double articulation used for the /b/ in the phrase “a web” produced by a 9-year-old boy with cleft palate. A normal pattern for /b/ in the same phrase is shown in (b).

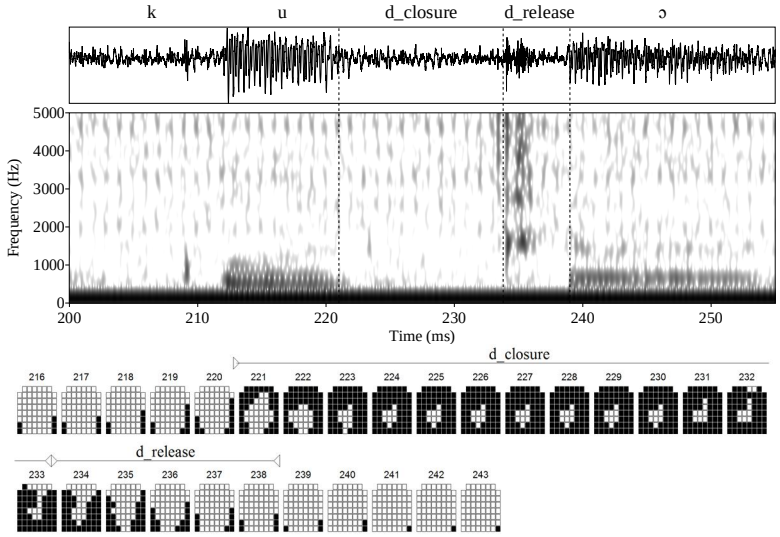
which occurred simultaneously with bilabial closure (although it is not possible to record bilabial closure from the EPG patterns, the investigators observed that bilabial closure occurred). The occurrence of simultaneous velar closure during bilabials were not detected perceptually during single word productions, which were almost always heard by listeners as normal bilabial productions, although listeners sometimes detected velar substitutions for bilabial targets during connected speech.

2.7.2. Alveolar-velar double articulations

Alveolar-velar double articulations [t͡k] and [d͡g] have been reported more frequently than bilabial-velar double articulations in children with cleft palate. For example, alveolar-velar double articulations have been identified as frequent errors in a longitudinal transcription-based study of children with cleft palate (Harding and Grunwell 1993). They found that half of the 26 children produced these double articulations at some stage in their phonetic development towards correct production of /t/ targets. In terms of EPG studies, Gibbon, Ellis and Crampin (2004) also found that alveolar-velar double articulations were frequently occurring errors, with 10 out of the 15 children they studied producing this type of double articulation. They used an EPG classification scheme to identify alveolar-velar double articulations in 15 children with cleft palate. Their results showed that alveolar targets /t/ and /d/ were more likely to be produced as alveolar-velar double articulations than velar targets /k/ and /g/. For example, 28% of alveolars and 12% of velars were produced in this way.

Although there are relatively few EPG studies of cleft palate speech in languages other than English, there is evidence that double articulations also occur in other languages, such as Cantonese (Whitehill et al. 1995). Figure 8 shows an example of alveolar-velar double articulation in Kalantanese (a Malay dialect) produced for a /d/ target and recorded from a 10-year-old boy with repaired cleft palate. In the articulation shown in Figure 8, which was typical of this boy's articulations for all alveolar targets, the onset of closure is in the alveolar region at frame 221, which is followed by simultaneous alveolar and velar closure from between frame 224–232, followed by the release of the alveolar closure at frame 233 and then velar release at frame 235.

(a) /d/ produced as [d͡g] by a 10-year-old Kalantanese boy with cleft palate.



(b) /d/ produced as [d] by a normal Kalantanese speaker.

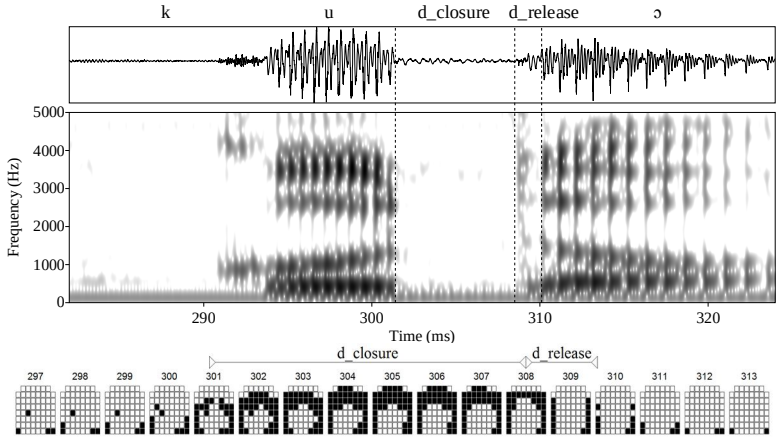


Figure 8. EPG data illustrating alveolar-velar double articulation. The EPG printouts in (a) show an alveolar-velar double articulation used for /d/ in the word "kuda" produced by a 10-year-old Kalantanese (a Malay dialect) boy with cleft palate. The word was produced in the Kalantanese sentence "daun muda makan ko kuda", which in English means "the young leaves are eaten by the horse". A normal pattern for /d/ produced by a Kalantanese speaker for the same phrase is shown in (b).

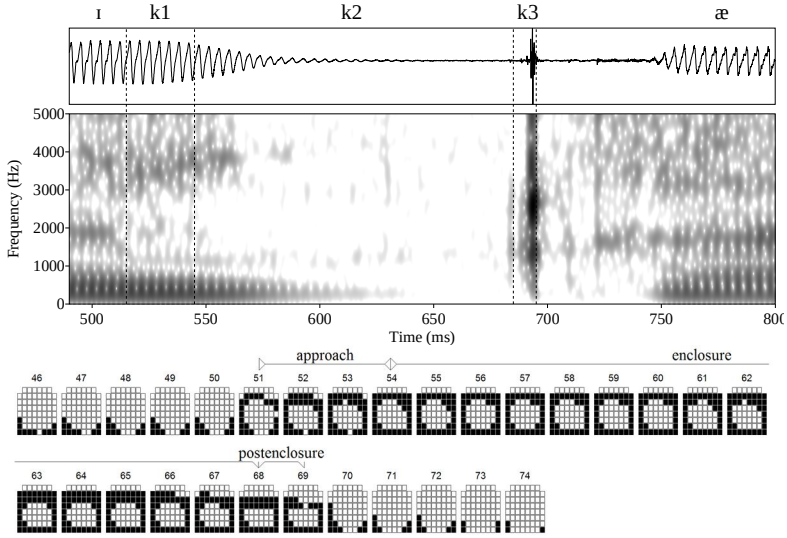
2.8. Clicks

Clicks are similar to the double articulations just described in that both involve velar closure occurring simultaneously with a second closure further forward in the oral cavity, either in the alveolar region or at the lips. They differ of course in the precise details of the timing and most importantly clicks involve a nonpulmonic, as opposed to a pulmonic, airstream mechanism. Unlike other types of compensatory errors already described, clicks are rarely reported in the cleft palate literature (see Miller's chapter on clicks in current volume). Howard (1993) reported a 6-year-old child with cleft palate who used bilabial clicks [ʘ] for /p/ targets. Peterson-Falzone, Hardin-Jones and Karnell (2001: 170) allude to the occurrence of clicks in some children with cleft palate, stating that they have "on rare occasion observed click substitutions of stop consonants in children with velopharyngeal inadequacy". A recent study by Mills, Gosling and Sell (2006) of 76 children with 22q11 deletion syndrome aged 3–10 years confirmed that clicks occur infrequently, with only a minority (4%) of this group producing these abnormal articulations.

Clicks are highly complex speech sounds that under normal circumstances occur almost exclusively in the languages of Southern Africa. Clicks are described as stops in which the essential component is "the rarefaction of air enclosed between two articulatory closures formed in the oral activity" (Ladefoged and Maddieson 1996: 246). Gibbon et al. (2008) reported perceptual and EPG data on clicks produced by two adolescents with VPD. The following EPG data are from one of the adolescents – a 14-year-old girl with ongoing VPD and associated hypernasality (Figure 9a). This girl was able to produce /d/, /k/, and /g/ targets as alveolar nasal clicks [!], and was able to produce them fluently in connected speech in all syllable and word positions. Clicks produced by this girl are probably abnormal compensatory articulations that are used in order to produce plosive sounds in the oral region of the vocal tract. This view is generally congruent with that of Warren and colleagues that compensatory articulations represent the speaker's attempt to achieve adequate pressure-valving for speech (Warren 1986; Warren, Dalston, and Dalston 1990).

Figure 9 shows that the click has an identifiable enclosure phase with simultaneous anterior and posterior closures (frames 54–68). At frame 69, enclosure terminates with the release of the anterior closure and the production of an audible click sound. A second feature is that clicks have

(a) /k/ produced as [!] by a 14-year-old girl with velocardiofacial syndrome.



(b) /k/ produced as [k] by a normal speaker.

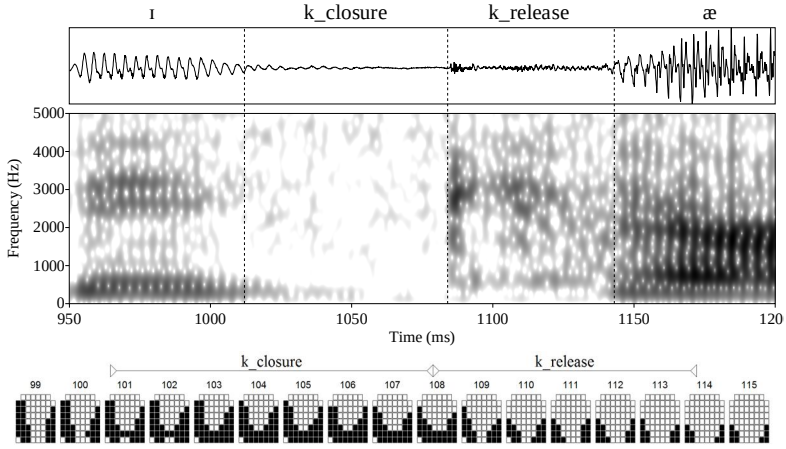


Figure 9. EPG data illustrating a nasal click produced as a substitution for /k/. The EPG printouts and acoustic trace in (a) show a click for the /k/ in the phrase "Happy Karen" produced by a 14-year-old girl with VPD. On the waveform, "k1" marks the approach phase (frames 51–54); "k2" marks the enclosure phase (frames 54–68); and "k3" marks the post-enclosure phase (frames 68–69). A normal pattern for /k/ in the same phrase is shown in (b).

an abruptness of the release of the anterior closure, and this can be seen clearly on the acoustic signal. The release goes from complete alveolar constriction to no contact without an intermediate phase showing fricative-like constriction. A third feature is evidence of the tongue blade moving backwards during enclosure (see frames 62–68). These features are consistent with previous studies of clicks in normal speakers of South African languages (Thomas 1997; Traill 1995). Thomas (1997: 382) showed in her EPG data a backward movement of the tongue blade during the enclosure phase of clicks, and suggests that "the fast movement of the tongue body in rarefaction, with its resulting large negative pressure, pulls the tongue tip backwards along the palate". Thomas suggested that the backward tongue blade movement is a strategy to facilitate tongue body lowering. In other words, downward movement of the tongue body, facilitated by tongue blade retraction, pulls the tongue blade back and abruptly away from the palate to produce the distinctive click sound.

2.9. Posterior nasal fricatives

Posterior nasal fricatives have been described radiographically by Trost (1981) as a substitution for alveolar and postalveolar fricatives and involving the velum approximating the posterior pharyngeal wall to create nasal turbulence or what is sometimes called "rustle". The movement of the velum can be seen using radiography as a blurring due to velar flutter. Although nasal turbulence can result in severely distorted speech, it is associated with a relatively small size of velopharyngeal gap compared to speakers with hypernasality (Kummer et al. 1992). These authors suggest that the nasal turbulence is generated by "friction of the air being forced through a small velopharyngeal gap" (Kummer et al. 1992: 155), and that this friction creates a more audible sound than through a larger opening when there is a larger gap size. The positive implication for the small velopharyngeal gap size is that speech therapy may be effective and should be attempted before embarking on surgical intervention.

Nasal misarticulations, similar to Trost's (1981) posterior nasal fricatives, have been described as occurring in Japanese speakers with cleft palate (Abe 1987). Yamashita et al. (1992) used EPG to describe three Japanese individuals with cleft palate whose speech contained what they called "nasopharyngeal misarticulations". The EPG data showed that all the speakers produced these abnormal articulations with complete closure

across the palate. Dent, Gibbon and Hardcastle (1992) found a similar pattern in a 9-year-old English speaking child with a cleft palate who produced complete contact in the velar region during /s/ and /z/ targets, which were heard by listeners as posterior nasal fricatives.

Figure 10a shows an example of EPG data with velar closure during a posterior nasal fricative. In this example, the EPG records show evidence of complete closure in the posterior region of the palate during the fricative noise. The presence of complete closure here suggests that air is escaping into the nasal cavity, and this is confirmed by the perceptual analysis of a posterior nasal fricative.

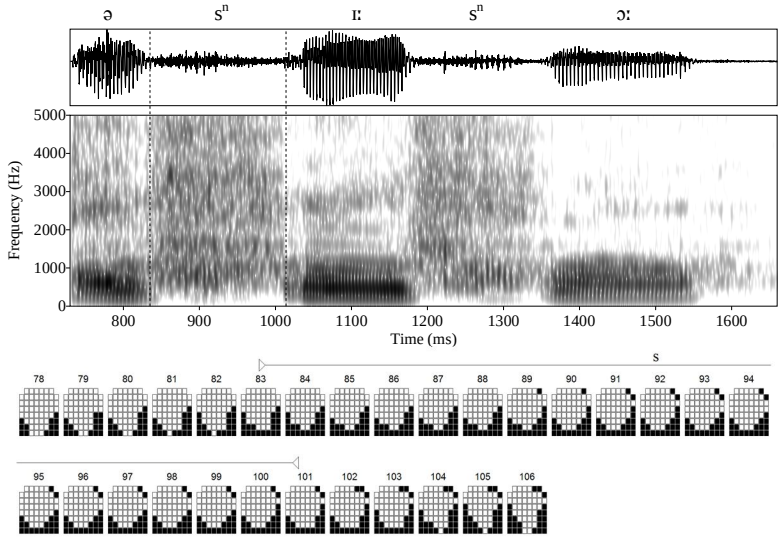
3. Abnormal articulations located below the velopharyngeal structures

The previous sections described abnormal articulations where at least one major constriction was located in the oral region. However, many compensatory articulation errors have their major constriction below, or upstream of, the velopharyngeal structures. Glottal and pharyngeal articulations are examples, but they involve minimal or no EPG contact (Gibbon 2004), and as a result, EPG data recorded during these productions are often not illuminating. The following sections therefore discuss studies that have used techniques other than EPG to investigate errors with primary constrictions below the velopharyngeal structures.

3.1. Glottal stops

Glottal stops are the most frequently reported type of compensatory articulations in individuals with cleft palate (Peterson-Falzone 1989; Peterson-Falzone, Hardin-Jones, and Karnell 2001; Trost-Cardamone 1990). Glottal stops are usually produced as substitutions for oral plosive consonants, and also less frequently for fricatives and affricates (Peterson-Falzone, Hardin-Jones, and Karnell 2001). A study of children with severe articulation disorders reported their use of glottal stops for liquids and glides (Bzoch 1965). Like pharyngeal stops, glottal stops can be "coarticulated" with other consonants, such as bilabial plosives and alveolar plosives, resulting in double articulations.

(a) /s/ produced as [s^n] by a 9-year-old with cleft palate.



(b) /s/ produced as [s] by a normal speaker.

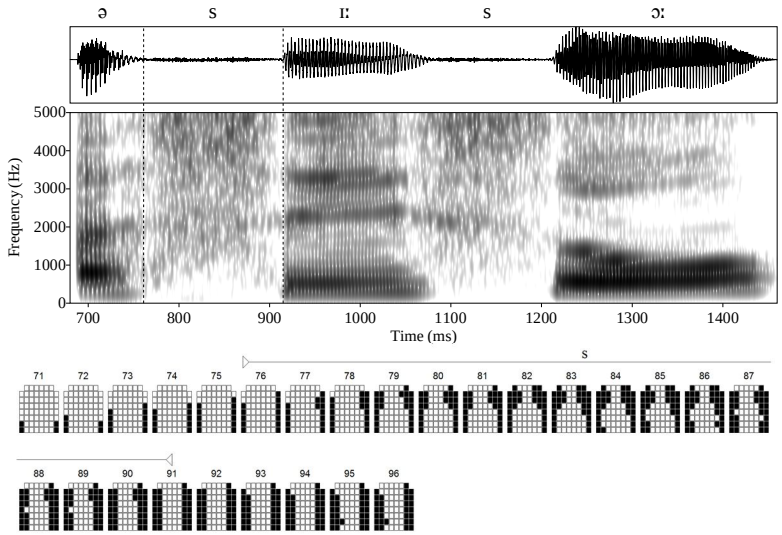


Figure 10. EPG data illustrating a nasopharyngeal fricative.The EPG printouts in (a) show a nasopharyngeal fricative used as a substitution for /s/ in the phrase “a seesaw” produced by a 9-year-old boy with cleft palate. A normal pattern for /s/ for the same phrase is shown in (b).

Glottal stops are stop consonants produced at the level of the glottis, which begins with a forceful adduction of the vocal folds and build up of sub-glottal pressure, followed by the sudden opening of the vocal folds to release the pressure (Kummer 2001). Abnormal laryngeal constriction was reported in 15 out of 26 individuals with cleft palate or VPD who produced glottal stops (Kawano et al. 1997). They showed constriction of the whole larynx comprising the adducting elevation of arytenoids, approximation or contact of arytenoids with the epiglottis, and medial movement of the bilateral aryepiglottic folds. These authors found that constriction of the larynx with the adducting arytenoids elevated towards the epiglottis appears to enhance plosive production.

Using cineradiography, Henningsson and Isberg (1986; 1991) showed that limited or no velopharyngeal movement may be associated with glottal stop substitutions in speakers with repaired cleft palate. They found good to moderate velopharyngeal movement during non-glottal stop production; moderate, insufficient, or poor movement when producing weak pressure consonants; whereas poor to no velopharyngeal movement during production of glottal stops (see Figure 11). The findings supported the notion that glottal stop substitutions are compensatory articulations because the air stream was stopped at the glottis which is upstream from the velopharyngeal structures; velopharyngeal closure thus becoming unnecessary (Henningsson and Isberg 1991).

It should be noted that glottal stops (referred to as preglottalization and glottalling) are part of normal English speech in certain phonetic contexts (Crystal 2005; Docherty et al. 1997; Ladefoged 2005; Wells 1982). It is important to distinguish between glottal stops that are produced as a normal part of everyday speech from those that are abnormal due to, for example, compensatory articulations in cleft palate speech. In terms of normal speech, Wells defined preglottalization as the insertion of a glottal stop /ʔ/ before voiceless plosives /p/, /t/, /k/, and affricate /tʃ/ when these consonants are in syllable-final position, preceded by a vowel, a liquid, or a nasal (e.g. “equal” is produced as /ˈiːʔkwəl/; “teacher” is produced as /ˈtiːɬtʃə/) (Wells 1982).

Glottalling, on the other hand, is the use of glottal stop to replace voiceless plosive /t/, and sometimes also /p/ and /k/. Glottalling is observed in many English accents (Wells 1982). For example, normal speakers can use the glottal stop for intervocalic /t/, so “butter” is realized as /ˈbʌʔə/, “bottle” is realized as /ˈbɒʔo/ (Ladefoged 2005; Wells 1982). In addition, nowadays some, particularly younger, speakers produce glottal stops at the

ends of words such as “cap”, “cat”, and “back” (Ladefoged 2005). In American English, glottal stops are often produced in words such as “button” and “bitten”. Glottal stops are therefore an integral part of normal speech where they occur in specific phonetic contexts and accents, and should not be judged as abnormal except where they occur in other situations. This view contrasts directly with Larsen (2003: 557), who in our view stated erroneously that the glottal stop “represents substandard articulation, and may be heard in the speech of both the general population and the cleft population. Its use should be discouraged in both populations”.

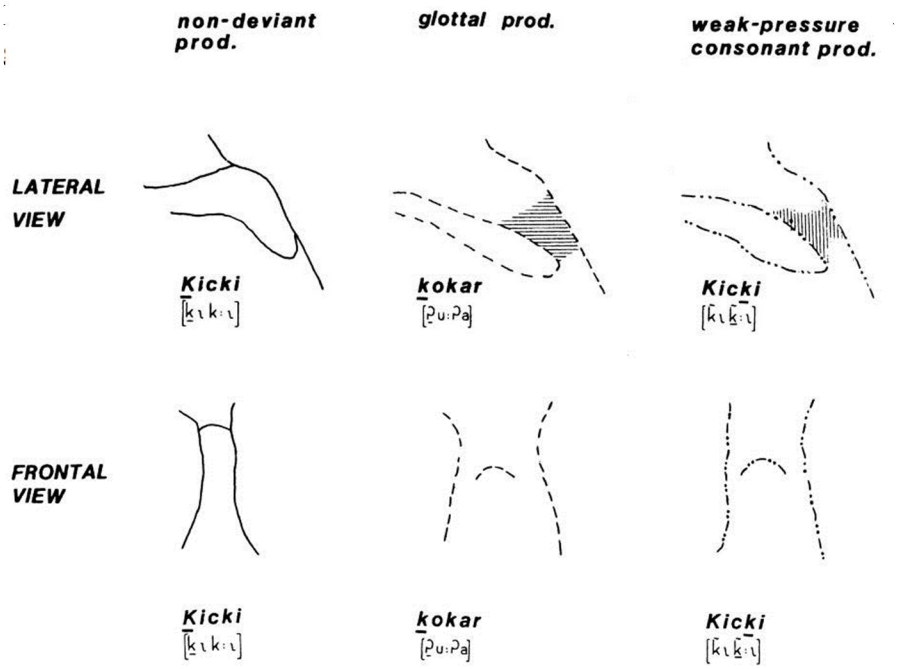


Figure 11. Tracings of velopharyngeal movements of a single speaker from cineradiographic frames for non-deviant, glottal, and weak-pressure consonant production, respectively. Shadowed areas indicate the position of pharyngeal flap. Good velopharyngeal movements were observed during non-glottal stop production (solid line) (adapted with permission from Henningsson and Isberg, 1991).

3.2. Pharyngeal stops

Pharyngeal stops can be produced as substitutions for plosive targets, particularly /k/. Trost (1981) described how the pharyngeal stop can be produced at various locations in the pharynx, from high (oropharynx) to low (epiglottis). Kawano and colleagues' fluorovideoradiographic data confirmed Trost's radiographic findings, and they found some interesting additional features of the pharyngeal stop (Kawano et al. 1997). First, Kawano et al. (1997) found that a higher place of articulation (with tongue base contacting at oropharynx) was more frequently observed in older children and adults, and a lower site (at oro- and laryngopharynx) was more frequently seen in younger children. Second, several studies have noted that the pharyngeal stop is greatly influenced by preceding and following sounds (Brooks, Shelton, and Youngstrom 1965; Honjow and Isshiki 1971; Kawano et al. 1997; Trost 1981). These studies showed that pharyngeal stops occur primarily in the context of low/back vowels, such as /a/, /o/, /u/ but not high/front vowels such as /i/, /e/ (/k/ in these contexts was often produced correctly or as other types of errors). Their explanation of the vowel effect was that the production of pharyngeal stops involves the base of the tongue, and the pharyngeal location is too distal anatomically from that of the high vowels.

3.3. Pharyngeal/glottal fricatives and affricates

Pharyngeal fricatives are produced by a constriction between the tongue dorsum and the posterior pharyngeal wall (Morley 1970; Morris 1972; Trost 1981), and are most frequently seen as substitutions for oral fricatives. Kawano et al. (1997) used fiberscopy and fluorovideographic analysis of a large group of over 250 individuals with cleft palate in order to investigate abnormal articulations that were judged perceptually as pharyngeal fricatives and affricates. They found that of 20 individuals (7.5% of whole group) whose /ʃ/ and /s/ were judged as pharyngeal, the overwhelming majority (19) articulated the fricatives at the level of the larynx, with just 1 individual articulating at the pharynx. Similarly, of 20 individuals whose /tʃ/ and /ts/ were judged as pharyngeal, 16 were found to produce the sound at the level of the larynx. More specifically, these fricatives and affricates were produced in a narrow space between the arytenoids and epiglottis, or between the epiglottis and posterior pharyngeal

wall or at both locations. Like the glottal stops, Kawano et al. (1997) found that velopharyngeal closure did not occur at the time the laryngeal sounds were produced, irrespective of whether the speaker had velopharyngeal competence. These authors concluded that in the overwhelming majority of cases, articulation errors that are heard as pharyngeal fricatives and affricates are much more likely to be in reality laryngeal fricatives and affricates. Kawano et al.'s study showed that distinguishing pharyngeal from laryngeal placement is difficult based on perceptual analysis alone, and that instrumental procedures greatly assist in the diagnostic process.

4. Summary

This chapter has illustrated how individuals with cleft palate produce a variety of distortions and substitutions in their efforts to produce turbulent speech sounds. Many atypical articulations are "compensatory errors". The concept of compensatory errors is important in understanding the nature and treatment of articulation errors associated with cleft palate speech. In essence, compensatory errors are thought to arise as a result of abnormal learning, and not as a direct consequence of the structural abnormality. Consequently, these errors often persist in speech even when vocal tract function has improved through surgical or orthodontic intervention.

The presence of compensatory articulatory errors at any point in an individual's development illustrates the complex relationship between vocal tract structure, function and quality of speech. This relationship means that the diagnosis of articulation difficulties in individuals with cleft palate requires close cooperation between a highly specialist multidisciplinary team. Team work is especially important to define the precise nature and extent of ongoing structural abnormalities, and the likelihood of improvement with surgical, medical, orthodontic or speech and language therapy intervention. These are highly complex tasks. For example, it has been shown that it is difficult to assess velopharyngeal function for speech when a speaker uses predominantly glottal articulations. Perceptual analysis combined with instrumental investigations of speech, such as those illustrated in this chapter, are important in making an accurate speech diagnosis.

Another factor that can give rise to individual differences in speech production is that speakers find different "solutions" when faced with similar structural anomalies. For instance, there are a number of possible

ways to produce plosive sounds in the context of VPD. A speaker could produce a click or a glottal stop; both would achieve the same goal of plosion but using different articulatory mechanisms. Another possibility is that the speaker uses the tongue body to aid velopharyngeal closure, so-called "lingual assistance" (Brooks, Shelton Jr., and Youngstrom 1965; Trost 1981). Finally, a speaker may not make any attempt to compensate for the presence of VPD, with the result that obstruent targets are produced as weak pressure consonants, consonants with nasal emission or nasal consonants. Thus, individuals with similar anatomical abnormalities may present with quite different patterns of speech errors.

Accurate diagnosis is an essential prerequisite to effective intervention, underscoring the importance of a multidisciplinary approach. Many of the compensatory errors described in this chapter are amenable to positive behavioural change with speech therapy. Visual feedback using EPG has been found to be beneficial in establishing correct placement for obstruent targets located on the hard palate in children and adults with cleft palate (Dent, Gibbon, and Hardcastle 1992; Gibbon and Hardcastle 1989; Whitehill, Stokes, and Man 1996). Other studies have shown that apparently faulty velopharyngeal function can improve spontaneously by correcting abnormal compensatory articulations (Kawano et al. 1997). Other interventions are equally important because they can help prevent abnormal articulations arising in the first place. For example, speech therapy can help very young children expand their sound inventories using naturalistic speech therapy methods. Scherer (1999) has found that indirect therapy to develop vocabulary in young children with cleft palate was effective in increasing consonant inventories and reducing the production of glottal stops. With appropriate early management such as this, it is realistic to expect that most individuals born with cleft palate will attain speech that is indistinguishable from their typically developing peers within the preschool years.

5. Acknowledgements

We thank Rosmawati Aman for the Kalantanese EPG data. The research reported in this chapter was supported by various project grants including: BBC Children in Need; London Law; and Henry Smith Charity. We thank Alan Wrench who designed the EPG system.

Notes

1. Gibbon et al. (2007) compared the tongue-palate contact patterns between oral alveolar stops /t/ and /d/ and nasal alveolar stop /n/. They found that all stops showed similar spatial patterns, however, the oral alveolar stops had more contact and were more likely to have bilateral constriction than the nasal counterpart.

References

Abe, Masako
1987 Pathophysiology of nasopharyngeal articulation: sound analysis and observation of articulatory movement. *The Japan Journal of Logopedics and Phoniatrics (Japanese) 28*: 239–250.

Albery, Elizabeth
1991 Consonant articulation in the different types of cleft lip and palate. M. Phil. thesis, Leicester Polytechnic.

Albery, Elizabeth, and Pamela Grunwell
1993 Consonant articulation in different types of cleft lip and palate. In *Analysing Cleft Palate Speech,* Pamela Grunwell (ed.), 83–111. London: Whurr Publishers.

Ball, Martin J. (ed.)
1993 *Phonetics for Speech Pathology*. 2nd ed. London: Whurr Publishers.

Brooks, Alta R., Ralph L. Shelton Jr., and Karl A. Youngstrom
1965 Compensatory tongue-palate-posterior pharyngeal wall relationships in cleft palate. *Journal of Speech and Hearing Disorders 30*: 166–173.

Bzoch, Kenneth R.
1965 Articulatory proficiency and error patterns of preschool cleft palate and normal children. *Cleft Palate Journal 2*: 340–349.

Chapman, Kathy L.
1991 Vocalizations of toddlers with cleft lip and palate. *Cleft Palate-Craniofacial Journal 28*: 172–178.

Chapman, Kathy. L., Mary Hardin-Jones, Julie Schulte, and Kelli Ann Halter
2001 Vocal development of 9-month-old babies with cleft palate. *Journal of Speech, Language, and Hearing Research 44*: 1268–1283.

Cohen, Steven R., Joseph Kalinowski, Don LaRossa, and Peter Randall
1991 Cleft palate fistulas: A multivariate statistical analysis of prevalence, etiology, and surgical management. *Plastic and Reconstructive Surgery 87*: 1041–1047.
Crystal, David
2005 *The stories of English*. London: Penguin.
Dalston, Rodger M.
1992 Timing of cleft palate repair: a speech pathologist's viewpoint. *Problems in Plastic and Reconstructive Surgery 2*: 30–38.
Dent, Hilary, Fiona Gibbon, and William Hardcastle
1992 Inhibiting an abnormal lingual pattern in a cleft palate child using Electropalatography. In *Interdisciplinary Perspectives in Speech and Language Pathology*, Margaret M. Leahy and Jeffrey L. Kallen (eds.), 211–221. Dublin: School of Clinical Speech and Language Studies.
Docherty, Gerard J., Paul Foulkes, James Milroy, Lesley Milroy, and David Walshaw
1997 Descriptive adequacy in phonology: A variationist perspective. *Journal of Linguistics 33*: 275–310.
Fujimura, Osamu, Tatsumi, I. F., and Kagaya, R.
1973 Computational processing of palatographic patterns. *Journal of Phonetics 1*: 47–54.
Gibbon, Fiona E.
2004 Abnormal patterns of tongue-palate contact in the speech of individuals with cleft palate. *Clinical Linguistics and Phonetics 18*: 285–311.
Gibbon, Fiona E., and Lisa Crampin
2001 An electropalatographic investigation of middorsum palatal stops in an adult with repaired cleft palate. *Cleft Palate-Craniofacial Journal 38*: 96–105.
Gibbon, Fiona E., and Lisa Crampin
2002 Labial-lingual double articulations in speakers with cleft palate. *Cleft Palate-Craniofacial Journal 39*: 40–49.
Gibbon, Fiona E., Lucy Ellis, and Lisa Crampin
2004 Articulatory placement for /t/, /d/, /k/ and /γ/ targets in school age children with speech disorders associated with cleft palate. *Clinical Linguistics and Phonetics 18*: 391–404.
Gibbon, Fiona E., and William Hardcastle
1989 Deviant articulation in a cleft palate child following late repair of the hard palate: A description and remediation procedure using electropalatography. *Clinical Linguistics and Phonetics 3*: 93–110.
Gibbon, Fiona E., Alice Lee, and Ivan Yuen

2007 Tongue-palate contact during bilabials in normal speech. *Cleft Palate-Craniofacial Journal 44*: 87–91.

Gibbon, Fiona E., Alice Lee, Ivan Yuen, and Lisa Crampin
2008 Clicks produced as compensatory articulations in two adolescents with velocardiofacial syndrome. *Cleft Palate-Craniofacial Journal 45*: 381–392.

Gibbon, Fiona E., Ivan Yuen, Alice Lee, and Lynne Adams
2007 Normal adult speakers' tongue palate contact patterns for alveolar oral and nasal stops. *Advances in Speech–Language Pathology 9*: 82–89.

Grunwell, Pamela
1993 *Analysing cleft palate speech.* London: Whurr Publishers.

Grunwell, Pamela, and Jane Russell
1988 Phonological development in children with cleft lip and palate. *Clinical Linguistics and Phonetics 2*: 75–95.

Hardcastle, William J., and Fiona E. Gibbon
1997 Electropalatography and its clinical applications. In *Instrumental Clinical Phonetics*, Martin J. Ball and Chris Code (eds.), 149–193. London: Whurr Publishers.

Hardcastle, William J., Fiona E. Gibbon, and Wilf Jones
1991 Visual display of tongue-palate contact: electropalatography in the assessment and remediation of speech disorders. *British Journal of Disorders of Communication 26*: 41–74.

Hardcastle, William J., Rosemarie Morgan Barry, and Marion Nunn
1989 Instrumental articulatory phonetics in assessment and remediation: case studies with the electropalatograph. In *Cleft Palate: The Nature and Remediation of Communicative Problems* Jackie Stengelhofen (ed.), 136–164. Edinburgh: Churchill Livingstone.

Hardin-Jones, Mary A., and David L. Jones
2005 Speech production of preschoolers with cleft palate. *Cleft Palate-Craniofacial Journal 42*: 7–13.

Harding, Anne, and Pamela Grunwell
1993 Relationship between speech and timing of hard palate repair. In *Analysing Cleft Palate Speech,* Pamela Grunwell (ed.), 48–82. London: Whurr Publishers.

Henningsson, Gunilla, and Annika Isberg
1986 Velopharyngeal movement patterns in patients alternating between oral and glottal articulation: A clinical and cineradiographical study. *Cleft Palate Journal 23*: 1–9.
1991 A cineradiographic study of velopharyngeal movements for deviant versus nondeviant articulation. *Cleft Palate-Craniofacial Journal 28*: 115–118.

Hiki, Shizuo, and Hidemi Itoh
1986 Influence of palate shape on lingual articulation. *Speech Communication 5*: 141–158.
Hixon, Thomas
1966 Turbulent noise sources for speech. *Folia Phoniatrica 18*: 168–182.
Honjow, Iwao, and Nobuhiko Isshiki
1971 Pharyngeal stop in cleft palate speech. *Folia Phoniatrica 23*: 347–354.
Howard, Sara J.
1993 Articulatory constraints on a phonological system: A case study of cleft palate speech. *Clinical Linguistics and Phonetics 7*: 299–317.
1998 A perceptual and electropalatographic case study of Pierre Robin Sequence. In *Clinical Phonetics and Linguistics*, Wolfram Ziegler and Karin Deger (eds.), 157–164. London: Whurr Publishers.
Howard, Sara J., and Caroline Pickstone
1995 Cleft palate: Perceptual and instrumental analyses of a phonological system. In *Case Studies in Clinical Linguistics*, Michael Perkins and Sara Howard (eds.), 65–90. London: Whurr Publishers.
Hutters, Birgit, Anja Bau, and Kirsten Brøndsted
2001 A longitudinal group study of speech development in Danish children born with and without cleft lip and palate. *International Journal of Language and Communication Disorders 36*: 447–470.
Kawano, Michio, Nobuhiko Isshiki, Iwao Honjo, Hisayoshi Kojima, Kyosuke Kurata, Fumiko Tanokuchi, Naohiro Kido, and M. Isobe
1997 Recent progress in treating patients with cleft palate. *Folia Phoniatrica et Logopaedica 49*: 117–138.
Krause, Charles J., Rosemary F. Tharp, and Hughlett L. Morris
1976 A comparative study of results of the Von Langenbeck and the V-Y pushback palatoplasties. *Cleft Palate-Craniofacial Journal 13*: 11–19.
Kummer, Ann W.
2001 Cleft palate and craniofacial anomalies: The effects of speech and resonance. San Diego: Singular.
Kummer, Ann W., Cindy Curtis, Melissa Wiggs, Linda Lee, and Janet L. Strife
1992 Comparison of velopharyngeal gap size in patients with hypernasality, hypernasality and nasal emission, or nasal

turbulence rustle) as the primary speech characteristic. *Cleft Palate-Craniofacial Journal 29*: 152–156.

Ladefoged, Peter
2005 *Vowels and consonants.* 2nd ed. Oxford: Blackwell.

Ladefoged, Peter, and Ian Maddieson
1996 *Sounds of the world's languages*. Oxford: Blackwell.

Larsen, Robert E.
2003 "Stops" in speech. *Cleft Palate-Craniofacial Journal 40*: 557.

McWilliams, Betty Jane, Hughlett L. Morris, and Ralph L. Shelton
1990 *Cleft palate speech.* 2nd ed. Philadelphia: B. C. Decker.

Michi, Ken-ichi, Yukari Yamashita, Satoko Imai, and Kohsuke Ohno
1990 Results of treatment of speech disorders in cleft palate patients: Patients obtaining adequate velopharyngeal function. In *Craniofacial anomalies and clefts of the lip, alveolus and palate* Gerhard. Pfeifer (ed.), 419–423. Stuttgart: Thieme.

Mills, Louise, Anne Gosling, and Debbie Sell
2006 Extending the communication phenotype associated with 22q11.2 Microdeletion Syndrome. *Advances in Speech-Language Pathology 8*: 17–27.

Moin, Parviz, and John Kim
1997 Tackling turbulence with supercomputers. *Scientific American 276*: 62–68.

Morley, Muriel E.
1970 *Cleft palate and speech.* 7th ed. Edinburgh: Livingstone.

Morris, Hughlett L.
1972 Cleft palate. In *Communicative disorders: An appraisal*, Alan J. Weston (ed.), 128–160. Springfield, IL: Charles C Thomas.

Netsell, Ronald
1990 Commentary. *Cleft Palate Journal 27*: 58–60.

O'Gara, Mary M., and Jerilyn A. Logemann
1988 Phonetic analyses of the speech development of babies with cleft palate. *Cleft Palate Journal 25*: 122–134.

Paliobei, Vassiliki, Anestis Psifidis, and Dimitrios Anagnostopoulos
2005 Hearing and speech assessment of cleft palate patients after palatal closure: Long-term results. *International Journal of Pediatric Otorhinolaryngology 69*: 1373–1381.

Peterson-Falzone, Sally J.
1989 Compensatory articulations in cleft palate speakers: Relative incidence by type. *Proceedings of the International Congress on Cleft Palate and Related Craniofacial Anomalies*, Jerusalem, Israel.
1990a A cross-sectional analysis of speech results following palatal closure. In *Multidisciplinary management of cleft lip and*

palate, Janusz Bardach and Hughlett L. Morris (eds.), 750–756. Philadelphia: W. B. Saunders.

1990b Speech disorders associated with dentofacial anomalies. In *Pediatric oral and maxillofacial surgery*, Leonard B. Kaban (ed.), 63–70. Philadelphia: W. B. Saunders.

Peterson-Falzone, Sally J., Mary A. Hardin-Jones, and Michael P. Karnell
2001 *Cleft palate speech.* 3rd ed. St. Louis: Mosby.

Peterson-Falzone, Sally J., Judith E. Trost-Cardamone, Michael P. Karnell, M. P., and Mary A. Hardin-Jones
2006 *The clinician's guide to treating cleft palate speech*. St. Louis: Mosby.

Phua, Yun Shan, and Tristan de Chalain
2008 Incidence of oronasal fistulae and velopharyngeal insufficiency after cleft palate repair: An audit of 211 children born between 1990 and 2004. *Cleft Palate-Craniofacial Journal 45*: 172–178.

Scobbie, James M., Sara E. Wood, and Alan A. Wrench
2004 Advances in EPG for treatment and research: An illustrative case study. *Clinical Linguistics and Phonetics 18*: 373–389.

Scherer, Nancy J.
1999 The speech and language status of toddlers with cleft lip and/or palate following early vocabulary intervention. *American Journal of Speech Language Pathology 8*: 81–93.

Sell, Debbie, Anne Harding, and Pamela Grunwell
1994 A screening assessment of cleft palate speech Great Ormond Street Speech Assessment. *European Journal of Disorders of Communication 29*: 1–15.

Stengelhofen, Jackie
1989 The nature and causes of communication problems in cleft palate. In *Cleft Palate: The Nature and Remediation of Communication Problems*, Jackie Stengelhofen (ed.), 1–30. Edinburgh: Churchill Livingstone.

Stevens, Kenneth N.
1998 *Acoustic Phonetics*. Cambridge, MA: The MIT Press.

Stoel-Gammon, Carol
1985 Phonetic inventories, 15–24 months: A longitudinal study. *Journal of Speech and Hearing Research 28*: 505–512.

Suzuki, Noriko, Yukari Yamashita, Ken-ichi Michi, and Tadashi Ueno
1981 *Changes of the palatolingual contact during articulation therapy in the cleft palate patients: Observation by use of dynamic palatography.* Paper presented at the 4th International Congress of Cleft Palate and related Craniofacial Anomalies, Acapulco, Mexico.

Thomas, Kimberly
1997 EPG and aerodynamic evidence for the coproduction and coarticulation of clicks in IsiZulu. In *EUROSPEECH-1997*, George Kokkinakis, Nikos Fakotakis, and Evangelos Dermatas (eds.), 379–382. Retrieved July 4, 2006, from ISCA Archive: http://www.isca-speech.org/archive/eurospeech_1997

Traill, Anthony
1995 Place of articulation features for clicks: anomalies for universals. In *Studies in general and English phonetics in honour of Professor J. D. O'Connor*, Jack W. Lewis (ed.), 121–129. London: Routledge.

Trost, Judith E.
1981 Articulatory additions to the classical descriptions of the speech of persons with cleft palate. *Cleft Palate Journal 18*: 193–203.

Trost-Cardamone, Judith E.
1990 The development of speech: assessing cleft palate misarticulation. In *Cleft Lip and Palate: A System of Management*, Desmond A. Kernahan and Sheldon W. Rosenstein (eds.), 227–235. Baltimore: Williams and Wilkins.
1997 Diagnosis of specific cleft palate speech error patterns for planning therapy or physical management needs. In *Communicative disorders related to cleft lip and palate*, Kenneth. R. Bzoch (ed.), 313–330. Austin: Pro-ed.

Vallino, Linda D., and Bryan Tompson
1993 Perceptual characteristics of consonant errors associated with malocclusion. *Journal of Oral and Maxillofacial Surgery 51*: 850–856.

Vihman, Marilyn M., Marlys A. Macken, Ruth Miller, Hazel Simmons, and Jim Miller
1985 From babbling to speech: A re-assessment of the continuity issue. *Language 61*: 397–444.

Wada, Takuro, Motoyasu Yasumoto, Noriyuki Ikeoka, Yoshishige Fujiki, and Ryuichi Yoshinaga
1970 An approach for the cineflurographic study of articulatory movements. *Cleft Palate Journal 7*: 506–522.

Warren, Donald W.
1986 Compensatory speech behaviors in individuals with cleft palate: A regulation/control phenomenon? *Cleft Palate-Craniofacial Journal 23*: 251–260.

Warren, Donald W., Rodger M. Dalston, and Eileen T. Dalston
1990 Maintaining speech pressures in the presence of velopharyngeal impairment. *Cleft Palate Journal 27*: 53–58.

Wells, John C.
1982 *Accents of English I: An introduction*. Cambridge: Cambridge University Press.
Whitehill, Tara, Stephanie Stokes, William J. Hardcastle, and Fiona Gibbon
1995 Electropalatographic and perceptual analysis of the speech of Cantonese children with cleft palate. *European Journal of Disorders of Communication 30*: 193–202.
Whitehill, Tara L., Stephanie F. Stokes, and Yonnie H. Y. Man
1996 Electropalatography treatment in an adult with late repair of cleft palate. *Cleft Palate-Craniofacial Journal 33*: 160–168.
Witzel, Mary A.
1991 Speech evaluation and treatment. *Atlas of the Oral and Maxillofacial Surgery Clinics of North America 3*: 501–516.
Wrench, Alan A.
2007 Advances in EPG palate design. *Advances in Speech-Language Pathology 9*: 3–12.
Wyatt, Rosemary, Debbie Sell, Jane Russell, Anne Harding, Kim Harland, and Elizabeth Albery
1996 Cleft palate speech dissected: a review of current knowledge and analysis**.** *British Journal of Plastic Surgery 49*: 143–149.
Yamashita, Yukari, Ken-ichi Michi, Satoko Imai, Noriko Suzuki, and Hiroshi Yoshida
1992 Electropalatographic investigation of abnormal lingual-palatal contact patterns in cleft palate patients. *Clinical Linguistics and Phonetics 6*: 201–217.