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GLOTTAL REINFORCEMENT IN TELUGU CLEFT PALATE SPEECH: AN ACOUSTIC ANALYSIS[1]

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Abstract

Due to insufficient structure and functioning of the velopharyngeal mechanism, cleft palate speakers cannot achieve velopharyngeal closure necessary for the articulation of oral phonemes. The most vulnerable oral phonemes are obstruents, as they require a build-up of high intra-oral pressure. Such individuals develop variant articulations in an attempt to compensate for their inability to produce the target phonemes. Inadequate intra-oral pressure is compensated by shifting the location/articulation of oral sounds to a posterior position in the vocal tract where there is a greater amount of air pressure. Glottal reinforcement is one such compensatory articulation in which articulation of a target obstruent is preceded by a glottal stop [ʔ]. In normal speech, for instance, in English /p/, /t/, and /k/ are sometimes preceded by [ʔ] (Roach, 1973). However, in cleft palate speech, it is considered to be atypical because it is adopted as a compensatory strategy for substituting the target obstruents. The aim of this paper is to find out the nature of glottal reinforcement in Telugu cleft palate speech in terms of its frequency of occurrence, the vulnerable target obstruents, and its acoustic characteristics. The data consisted of 28 single words, 14 short sentences and connected speech obtained from 17 (8 female and 9 male aged between 9 and 16 years) native Telugu speakers with a repaired cleft lip and palate. The acoustic characteristics were studied on wideband spectrograms using PRAAT. The study revealed that there are two types of glottally reinforced articulations: glottally reinforced oral plosives and glottally reinforced nasals and approximants, which occur only in the intervocalic position.

Keywords: cleft palate, compensatory articulation, glottal reinforcement, acoustic analysis, PRAAT

0. INTRODUCTION

Cleft lip and/or palate is one of the most common congenital structural deformities which primarily affects the speech with reference to articulation, resonance, airflow, and voice quality. The most remarkable speech production problems demonstrated by cleft palate speakers are those related to Velopharyngeal Insufficiency (VPI), the insufficient structure and functioning of the velopharyngeal mechanism. Due to VPI, cleft palate speakers cannot achieve velopharyngeal closure (i.e. the soft palate does not extend enough to close the nasal cavity) necessary for the articulation of oral phonemes. As a result, they are not able to maintain the necessary intra-oral pressure for the articulation of obstruents,

[1] I am greatly indebted to Dr.C.Meena Debashish for introducing me to Acoustic Phonetics. I would like to thank for her insightful comments and productive discussions during the research.

and develop certain variant articulations in an attempt to compensate for their inability to produce the target phonemes. Inadequate intra-oral pressure is compensated by shifting the location/articulation of oral sounds to a posterior position in the vocal tract where there is a greater amount of air pressure. Glottal reinforcement is one such compensatory articulation frequently observed in cleft palate speech. The aim of this paper is to identify the characteristics of glottally reinforced articulations in Telugu[2] cleft palate (hereafter TCP) speech in terms of its frequency of occurrence, the vulnerable target obstruents, and its acoustic features.

1. Methodology

1.1 Subjects and Test Material

The subjects are 17 Telugu speaking individuals, eight girls and nine boys in the age group of 9 and 16 years, with a repaired cleft lip and palate. The subjects were grouped into three on the basis of the type of cleft: UCLP (unilateral cleft lip and palate), BCLP (bilateral cleft lip and palate), or CPO (cleft palate only). Subjects 1 to 8 belong to UCLP group, 9 to 15 to BCLP group, and 16 and 17 to CPO group.

A specifically devised test material (based on the recommendations of Henningsson *et al.* 2008) which consists of 28 single words and 14 short sentences was used.[3] In addition to this, natural speech was elicited through conversation/picture description task. 14 obstruents of Telugu (8 plosives, 2 affricates, and 4 fricatives) were considered as the target consonants as they are the most vulnerable speech sounds for cleft palate speakers. The target obstruents are listed in the following table.

Table 1. Target obstruents.

	Bilabial	***Dental***	***Alveolar***	***Alveo-***	***Retroflex***	***Velar***	***Glottal***

[2] Telugu is a Dravidian language. It is the official language of Andhra Pradesh and Telangana.

[3] Henningsson *et al.* (2008) recommend that a speech sample consisting of a controlled single word and sentence stimuli can be used to assess different aspects of cleft palate speech. They provide specific guidelines to be applied in the preparation of single words and sentences. Some of the essential guidelines include that all the test words should contain only one type of target obstruent per word, and the list should not include any nasal consonants etc. Based on these guidelines, single words and sentence stimuli were prepared in collaboration with a speech-language therapist who has been working in the cleft care field for five years. One of the major contributions of this research is the development of this test material which can specifically be used to assess Telugu cleft palate speech with all age groups.

				palatal			
Plosives	p b	t̪ d̪			ʈ ɖ	k g	
Affricates				tɕ dʑ			
Fricatives			S	ɕ	ʂ		h

For each target consonant, two words were listed, with the target consonant occurring in the word-initial (WI) and word-medial (WM) positions.[4]

1.2 Analysis of the data

The data was analyzed by employing a combination of perceptual and acoustic analysis. The speech was transcribed phonetically using IPA (2015), ExtIPA, and VoQS symbols (2008). Based on the transcription, the divergent patterns were identified and their acoustic characteristics were studied on wideband spectrograms using PRAAT (version 5.5.04). The frequency range was set to 0-5,000 Hz and the window length as 0.005 seconds to obtain wideband spectrograms.

2. Glottal reinforcement in Telugu cleft palate speech

Glottal reinforcement (also called glottalization or pre-glottalization) is the phenomenon of the occurrence of a phoneme simultaneously with a glottal stop. For instance, in English, /p/, /t/, and /k/ are sometimes preceded by [ʔ] as in /pɒʔpkɔːn/ *'popcorn'*, '/beʔtə/ *'better'*, /geʔtit/ *'get it'*, where oral closure of plosives is preceded by a glottal closure (Roach, 1973). In cleft palate speech, glottal reinforcement is considered to be atypical because the subjects adopt it as a compensatory strategy for substituting the target sounds.

In TCP speech, intervocalic glottally reinforced articulations were observed in ten subjects from all the three groups: S1, S5, and S6 (UCLP group), S10, S12, S13, S14, and S15 (BCLP group), and S16 and S17 (CPO group). Further, it was observed that the glottally reinforced

[4] Consonants do not occur in word-final position in Telugu.

articulations identified in TCP speech are of two types: **glottally reinforced oral plosives** and **glottally reinforced nasals and approximants**. These are discussed below.

2.1 Glottally reinforced oral plosives

The oral plosives which are mainly affected by glottal reinforcement are /p/, /b/, /t̪/, and /k/. /p/ and /b/ were realized as [ʔ͡p] and [ʔ͡b̥] respectively by S15, /t̪/ was realized as [ʔ͡t̪] by S13, and /k/ as [ʔ͡g] by S6 as seen in the following examples.

Eg:	[oa̰ʔ͡b̥a:jĩ:]	for	/o:abba:ji:/	*'one boy'*
	[k̪o:ʔ͡t̪ĩ]	for	/ko:t̪i/	*'monkey'*
	[ã:ʔ͡gũ]	for	/a:ku/	*'leaf'*

As Brondsted *et al.* (1994) describe, cleft palate speakers employ glottal reinforcement as a compensatory strategy to strengthen the oral plosive. The spectrogram of [a̰ʔ͡b̥a:] from the word [oa̰ʔ͡b̥a:jĩ:] (/o:abba:ji:/ *'one boy'*) of S15 is given in Figure 1 to describe the acoustic features of [ʔ͡b̥].

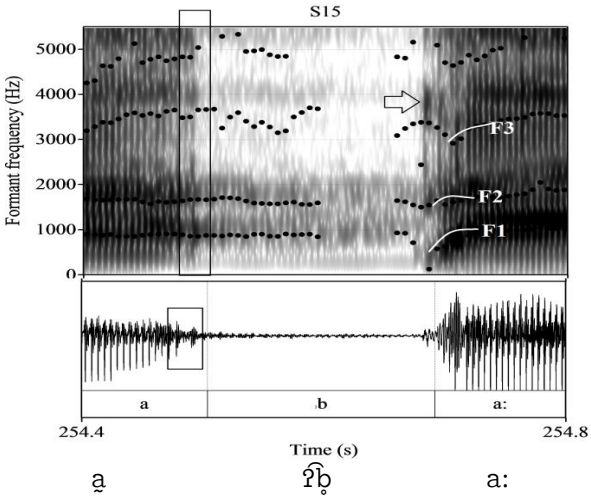

Figure 1. Spectrogram of [a̰ʔ͡b̥a:] from the word [oa̰ʔ͡b̥a:jĩ:] (/o:abba:ji:/[5] *'one boy'*) of S15 depicting acoustic features of [ʔ͡b̥].

[5] In this target word, there is gemination of /b/, however, the subject did not articulate it as a geminated /b/ instead articulated it as [ʔ͡b̥].

In the above spectrogram, closure duration of the intervocalic consonant is more when compared to a single occurrence of [ɓ], which indicates the presence of two consonants. But this is definitely not a case of gemination as both the auditory perception and the acoustic cues do not support it. Further, [ɓ] is devoiced which is due to the assimilatory effect of the preceding [ʔ]. The glottal reinforcement is also substantiated by the presence of creakiness[6] in the terminal portion of the preceding vowel (irregularly spaced glottal pulses are shown in box). For the second segment [ɓ̥], it can be observed that there is a release burst (shown with an arrow in the figure), and the rising F2 and F3 transitions from a lower to a higher frequency in the following vowel indicate its place of articulation i.e. bilabial. However, as /ɓ/ is devoiced here there is no voice bar.

2.2 Glottally reinforced nasals and approximants

Glottally reinforced nasals and approximants observed in TCP speech occur as substitutions for the target obstruents. These are summarized in Table 2.

Table 2. Targets articulated as glottally reinforced nasals and approximants.

Pattern	***Targets affected***	***Subjects***
[ʔ͡m]	/p/	S15
	/ɓ/	S1, S10, S12, S14, S17
[ʔ͡n̪]	/d̪/	S1, S10, S17
	/ɖ/	S1
	/dʐ/	S17
	/ɕ/	S15

[6] Gordon (2001) points out that the presence of glottal stops is often identified by the presence of creakiness on adjacent sounds. In creaky phonation, the posterior portions of the vocal cords are drawn together making the vocal cords thicker allowing the anterior portions to vibrate. Acoustically, it is characterized by irregularly spaced glottal pulses and reduced acoustic intensity.

[ʔ͡ɲ]	/dʑ/	S10
[ʔ͡j]	/ɖ/	S13
	/g/	S17
	/tɕ/	S1, S5, S10, S12, S16
	/dʑ/	S1, S12, S13
	/s/	S14
	/ʂ/	S17

As illustrated in Table 2, glottally reinforced bilabial nasal [ʔ͡m] was observed as a substitution for target bilabial plosives /p/ and /b/: voiceless /p/ was realized as [ʔ͡m] by S15, and the voiced /b/ as [ʔ͡m] by S1, S10, S12, S14, and S17. Another divergent pattern, glottally reinforced denti-alveolar nasal [ʔ͡n̪], occurs as a substitution for targets /d̪/, /ɖ/, /dʑ/, and /ɕ/. /d̪/ was realized as [ʔ͡n̪] by S1, S10, and S17; /ɖ/ as [ʔ͡n̪] by S1, /dʑ/ as [ʔ͡n̪] by S17, and /ɕ/ as [ʔ͡n̪] by S15. In addition to this, a glottally reinforced palatal nasal [ʔ͡ɲ] occurs in the speech of S10 as a substitution for /dʑ/.

Further, instances of glottally reinforced palatal approximant [ʔ͡j] were also observed. The affected targets are /ɖ/, /g/, /tɕ/, /dʑ/, /s/, and /ʂ/. /ɖ/ was realized as [ʔ͡j] by S13, /g/ as [ʔ͡j] by S17, /tɕ/ as [ʔ͡j] by S1, S5, S10, S12, and S16, /dʑ/ as [ʔ͡j] by S1, S12, and S13, /s/ as [ʔ͡j] by S14, and /ʂ/ as [ʔ͡j] by S17. A few examples are listed below.

Eg:	[mɑ̰:ʔ͡mũ]	for	/ba:bu/	*'boy'*
	[a̰ĩʔ͡n̪ũ]	for	/aid̪u/	*'five'*
	[ra:ʔ͡jũ:]	for	/ra:dʐu/	'*person's name'*
	[ĩ:ʔ͡ja:]	for	/si:sa:/	*'bottle'*

Glottal stop occurrence was more difficult to perceive when it preceded nasals and approximants than when it preceded the oral plosives. For instance, articulation of target /b/ in WM position in the word /ba:bu/ *'boy'* by S1 was initially perceived as just [m] rather than [ʔ͡m]. However, acoustic cues provide ample evidence for the occurrence of [ʔ] as seen in the spectrogram of [ɑ̰:ʔ͡mũ] (of S1) (Fig 2).

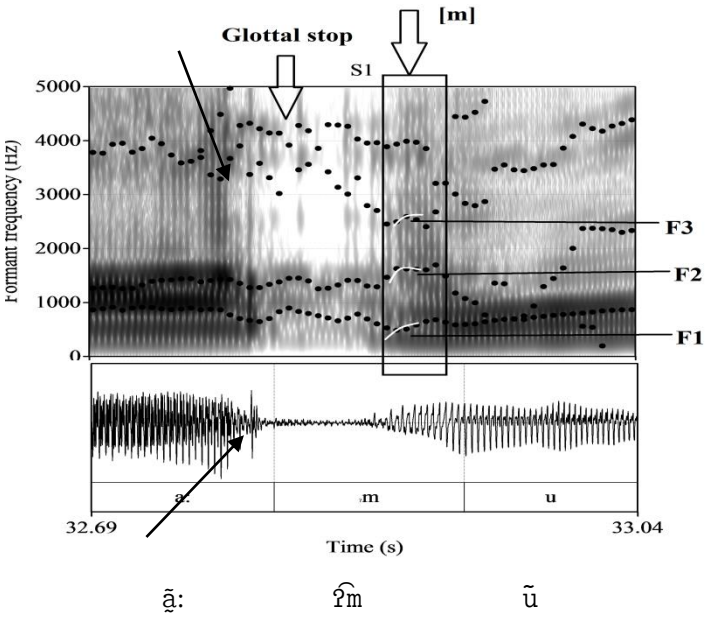

Figure 2. Spectrogram of [ɑ̰:ʔ͡mũ] from the word [mɑ̰:ʔ͡mũ] (/ba:bu/*'boy'*) of S1 depicting acoustic features of [ʔ͡m].

In the above figure, the acoustic cues for [ʔ] and the accompanying consonant (here [m]) in the intervocalic position can be observed. The adduction of the vocal cords for [ʔ] is

acoustically evident as a 'gap' in both the waveform and the spectrogram, which is further supported by the presence of creaky phonation (in the form of irregularly spaced glottal pulses) in the terminal portion of the preceding vowel (shown here with long arrows. This can be compared with Figure 1). The accompanying segment (marked [m] in the figure) displays lower energy and lighter formants than the following vowel. The formant values for this segment are: F1 around 250 Hz, F2 just below 2,000 Hz, and F3 around 3,000 Hz. Further, the formant transitions are from a lower to a higher frequency indicating a bilabial articulation.

The following is a spectrogram of [ẽːʔ͡jũ] (/eːɖu/ *'seven'*) of S13, who realized target /ɖ/ as [ʔ͡j].

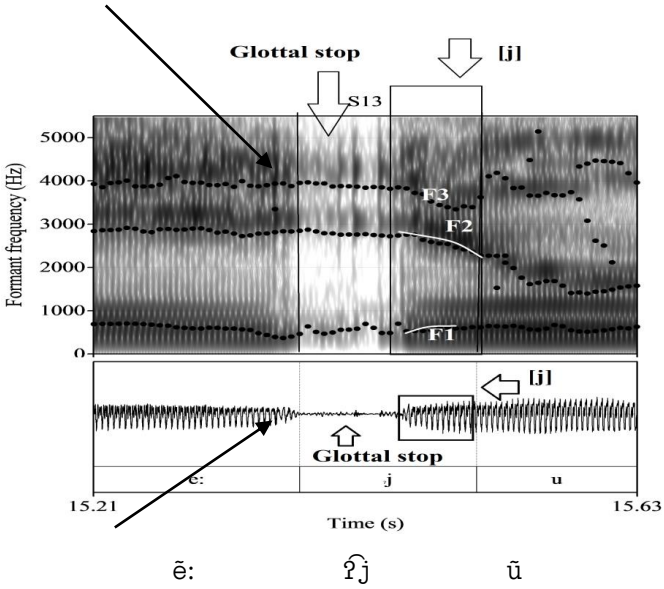

Figure 3. Spectrogram of [ẽːʔ͡jũ] (/eːɖu/ *'seven'*) of S13 depicting acoustic features of [ʔ͡j].

In Figure 3, it can be observed that [ʔ] is accompanied by a palatal glide [j]. [ʔ] displays a closure duration, and [j] its formant structure: The irregular vertical striations seen during the [ʔ] and the terminal portion of the preceding vowel are indicative of creaky phonation; [j] has a formant structure similar to the high front vowel /i/ (as it is a glide from /i/ position to

the following vowel in a word). For the latter, there is a rise in F1 and a glide in F2 falling from high (around 2,800 Hz) to lower (2,200 Hz) frequency. F3 also drops from around 3,800 Hz to 3,400 Hz.

3. Conclusions

In TCP speech, glottally reinforced articulations were observed in ten subjects from all the three groups: S1, S5, and S6 (UCLP group), S10, S12, S13, S14, and S15 (BCLP group), and S16 and S17 (CPO group). This is an indication that it is a compensatory articulation adopted by the subjects of all cleft-types. Generally, in glottal reinforcement only the oral obstruents are preceded by [ʔ]. Interestingly, in TCP speech, two types of glottally reinforced articulations were observed in the intervocalic position: **glottally reinforced oral plosives** and **glottally reinforced nasals and approximants**. The oral plosives /p/, /b/, /t̪/, and /k/ were subjected to glottal reinforcement (ʔ͡p, ʔ͡b̥ ʔ͡t̪, and ʔ͡g). And, glottally reinforced bilabial nasal [ʔ͡m] as a substitution for bilabial plosives /p/ and /b/; glottally reinforced denti-alveolar nasal [ʔ͡n̪] for targets /d̪/, /ɖ/, /d□/, and /ɕ/; glottally reinforced palatal nasal [ʔ͡ɲ] for /d□/; and glottally reinforced palatal approximant [ʔ͡j] for targets /ɖ/, /g/, /tɕ/, /d□/, /s/, and /ʂ/ were observed. Glottal stop occurrence was difficult to perceive, however, the acoustic cues provided ample evidence for the occurrence of [ʔ] preceded by one of these oral plosives, nasals or approximants. The occurrence of glottal stop is substantiated by the closure duration of [ʔ] and presence of creakiness in the terminal portion of the preceding vowel.

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