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Acoustic Analysis of Glottal Stops in Tamil-Speaking Children with Cleft Lip and Palate

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Abstract

This study aims to analyze the acoustic parameters of glottal stop in children with unilateral cleft lip and palate. Eighteen subjects in the age range between 8 &13 years, substituting glottal stops for oral stop consonants in Tamil language participated in the study. A total of 1944 tokens were generated. Inter-rater reliability of the perceptual rating by the judges showed good agreement, Kappa of 0.72. Tokens were acoustically analyzed for the voice onset time (VOT), burst duration, burst frequency and Closure duration using PRAAT software version 5.1.25. Two types of waveform patterns were observed. Only acoustic parameter could be measured for class A glottal stop is closure duration. Whereas for class B glottal stops in addition to closure duration, VOT burst duration and could be measured. These results suggest that, inclusion of acoustic analysis in the comprehensive assessment will complement the findings of perceptual evaluation.

Keywords: Glottal stop; Acoustic analysis; Inter-rater reliability

Introduction

Acoustic analysis of compensatory articulation in individuals with cleft lip and palate (CLP) can provide an objective measure for use in combination with perceptual judgments to more accurately identify articulatory patterns. Glottal stops produced by individuals with CLP are described diversely using acoustic analysis (Kido et al, 1992). As studies pertaining to assessment of glottal stop produced by children with CLP are sparse, this study acoustically analyses perceptually identified glottal stops in this group. It also seeks to identify the distribution of glottal stops across different voiceless stop consonants in Tamil language.

Previous researchers have addressed similar topics and provided the groundwork for this research in other geographic and theoretical contexts. This research is based on the understanding that velopharyngeal dysfunction occurring along with CLP causes abnormal speech characteristics due to compensatory methods adopted during the learning stage (Kummer, 2008). Misarticulation is the major speech disorder in cleft lip and palate. Common error patterns seen in individuals with CLP are backing errors, nasal fricatives, nasal consonants for oral pressure consonants, nasalized voiced pressure consonants, weak oral pressure consonants, and other misarticulations involving lateralised or palatalised productions of fricatives and developmental articulation/phonological error (Nagarajan, Savitha & Subramaniyan, 2009).

The most common and distinctive compensatory articulation error in young children is glottal stop substitution (Peterson-Falzone, Hardin-Jones, & Karnell, 2010). It is very important to distinguish glottal stop from consonant omission while assessing cleft palate speech because these errors are produced differently. Glottal stops are produced with a rapid voice onset time, but in consonant omission the voice onset is smooth with the initiation of the vowel (Kummer, 2008). Earlier transcription and perceptual analysis was applied commonly to assess glottal stops. Though perceptual assessment is considered the "gold standard," it has proven to be difficult and subjective in nature. Complementing auditory perception with acoustic analysis may provide a basis for identifying and describing the glottal stop in cleft palate speech.

Acoustic analysis provides cues relevant to the articulatory dimension. Acoustic characteristics have an important role in tracking articulation errors (Huer, 1989). The acoustic parameters used for describing stop consonants are voice onset time (VOT), burst frequency, burst duration, closure duration and preceding vowel duration. Acoustic description of stop consonant production includes an initial period of occlusion followed by a transient explosion (20 msec) and then a period of frication (0-10 msec) followed by a period of aspiration (2-20 msec) with final transitions to the formant of the following vowel (Savithiri, 2004). Acoustic analysis has been widely applied in describing the articulatory errors in individuals with CLP.

Method

Subjects

Eighteen subjects (11 males & 7 females) with repaired unilateral CLP with the mean age of 11.8 years (SD of 3.3, & age range: 8 to 13 years) who came to tertiary health care centre participated in the study. All subjects were included after obtaining informed consent. Subjects were native Tamil-speaking individuals with non-syndromic CLP. Substitution of glottal stops for oral stop consonants was exhibited by all subjects. Detailed language evaluation confirmed age appropriate receptive and expressive language skills for all the subjects. Audiological evaluation on subjects revealed hearing sensitivity within normal limits (PTA≤25dBHL at 500, 1000, 2000 Hz).

Procedure

Development of Speech Tokens

Two native Tamil speakers selected 54 meaningful words from a Tamil dictionary such that these words included voiceless stop consonants (/p/, /t/, /k/, and /th/) in the medial position. A Linguist analyzed the words with respect to simplicity and eliminated words influenced by dialectal variation. Final list comprised of thirty-six words having bisyllabic and trisyllabic word structure. Bisyllable words contain CVCCV and CVCCVC syllable structure. Trisyllable words contain CVCCVCV and CVCCVCVC. The distribution of words across the sounds were as follows: seven words with /k/ sound, ten words each with /t/ and / t̪/ sounds and nine words with /p/ sound.

Recording of Speech Tokens

Recording was done in a sound treated room using Kay Elemetrics CSL software, model 4150 at a sampling rate of 20 kHz. The recording window was set to 300 seconds. All samples were recorded using a SM48- dynamic microphone placed at a distance of 15cms. Subjects were instructed to read the word three times at a habitual rate of speech and loudness. The recorded tokens were subjected for perceptual and acoustic analysis.

Perceptual Analysis

A total of 1944 tokens were generated. Two experienced speech language pathologists whose native language is Tamil served as judges. None of the judges were involved in development and recording of speech tokens. A perceptual rating for 'conspicuousness' of glottal stop in the recorded speech tokens was carried out. 1944 tokens were presented individually through headphones and judges were instructed to check for the occurrence of glottal stops at the medial position of the word. A 2-point rating scale was used (0-absence of glottal stop & 1-presence of glottal stop). Inter-rater reliability was assessed. 843 out of 1944 tokens were identified to have glottal stops and these tokens were subjected for acoustic analysis.

Acoustic Analysis

Acoustic analysis was carried out using PRAAT software version 5.1.25. Glottal stop segments were analysed by visual inspection of waveform and wide band spectrogram with band frequency set to 300 Hz. Speech tokens were analyzed for Voice Onset Time (VOT) in msec, Burst duration, Burst frequency and Closure duration.

Results

Perceptual Assessment of Glottal Stop

The results of the perceptual analysis are summarized in table 1. Judge 1 and Judge 2 agreed on 843 tokens for the presence of glottal stop and on 830 tokens for the absence of glottal stop. Kappa's inter-rater reliability test showed good agreement (k=0.72) between the ratings of the two judges.

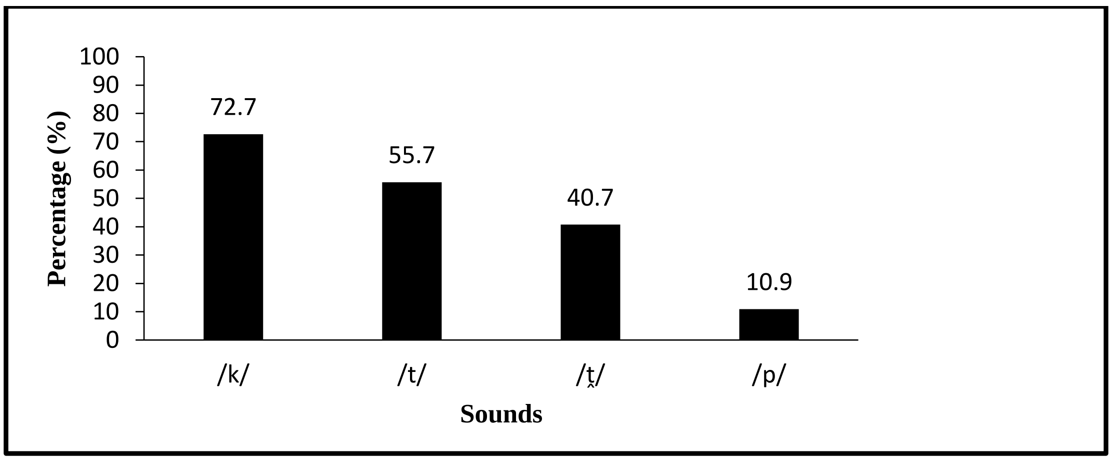
Table 1: Consensus matrix for ratings of glottal stops by judges

		Judge 1	
		Present	**Absent**
Judge 2	**Present**	843	198
	Absent	73	830

Occurrence of glottal stop across voiceless stop consonants

Maximum occurrence of glottal stop was noticed for the posterior most sound /k/ followed by the sounds /t/ and /t̪/. The least occurrence of glottal stop was observed for the anterior sound /p/ as shown in figure 1.

FIGURE 1: Occurrence of glottal stop in voiceless stop consonants



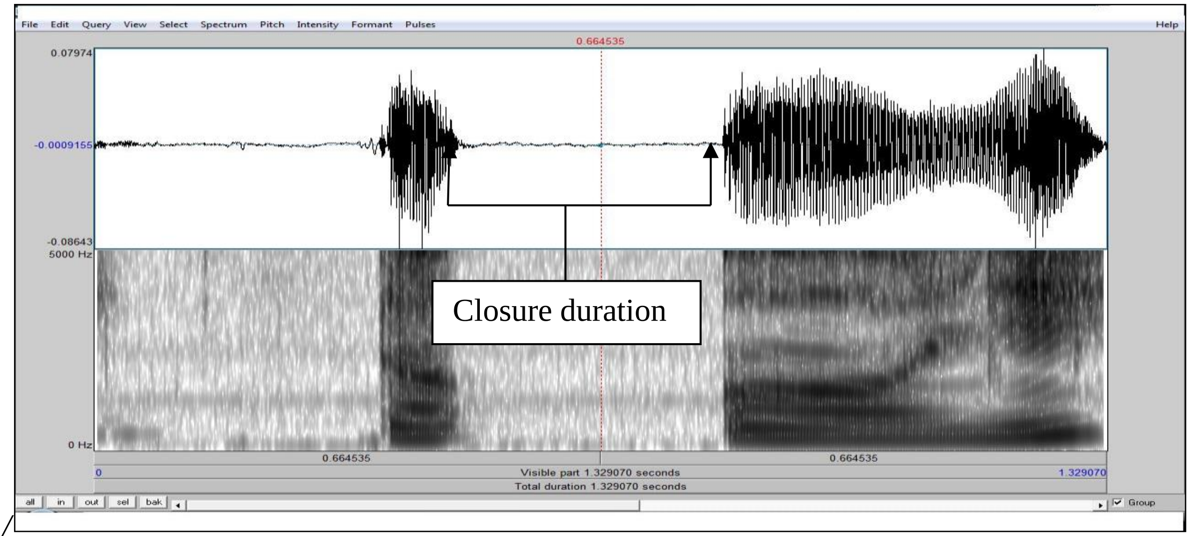
Acoustic Analysis of Glottal Stop

Two types of waveform patterns were observed during the visual inspection of tokens judged to have 'presence' of glottal stop. One type included waveform with simultaneous voicing without release burst and the other type of waveform consisted of lag voicing with release burst. For ease of reference these were labelled as class A and class B glottal stop.

Class A

Class A type had acoustic characteristics of simultaneous voicing with the glottal release. Since voicing starts simultaneously with glottal release, VOT could not be measured for Class A glottal stops. A spectrogram of the word /*t̪əkkəːli*/ uttered by an individual with CLP is shown in figure 2.

FIGURE 2: Spectrogram of class A glottal stop in medial position of word /*t̪ə**kk**əːli*/



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It is observed that closure duration of class A glottal stop obtained in this study is comparatively longer to that of the normal oral stops produced in Tamil language. Mean and standard deviation of closure duration of Class A glottal stop substituted for sounds /k/, /p/, /t/ and /t̪/ are tabulated in table 2.

TABLE 2: Mean and standard deviation of closure duration for class A glottal stop substituted for /k/, /t/, /t̪/ and /p/ sounds

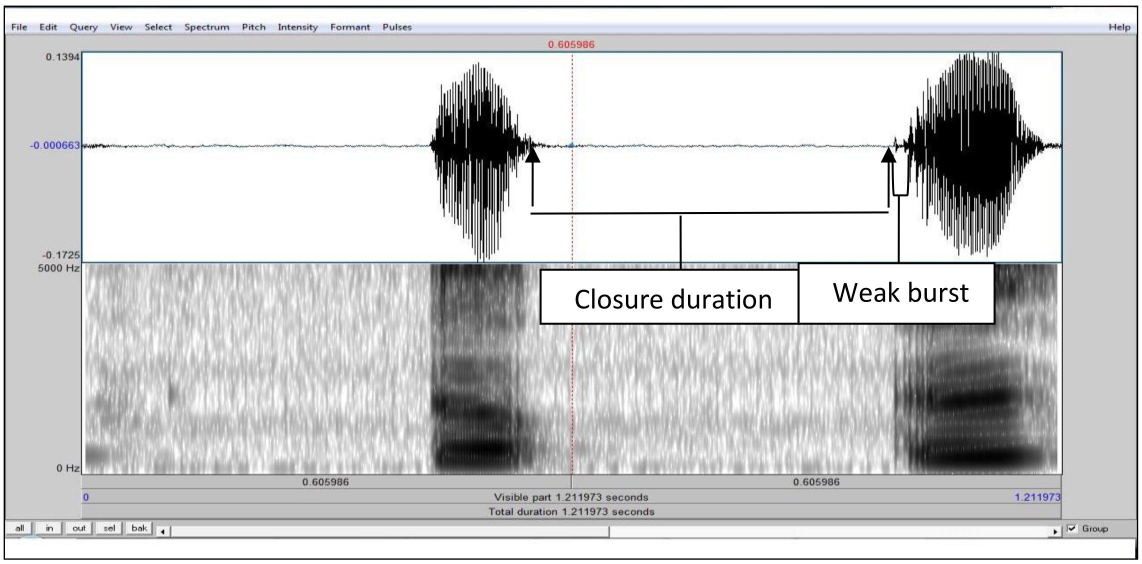
Sounds	Mean (msec)	Standard deviation
/k/	252.2	102.1
/t/	244.3	98.9
/t̪/	274.8	98.1
/p/	272.2	98.1

The acoustic feature measured for Class A glottal stop showed mean closure duration of 259.4 msec and standard deviation of 99.1. The mean value for closure duration of Class A glottal stop across the consonants showed minimum difference.

Class B

Class B glottal stop production is acoustically described by the period of glottal closure followed by a weak burst segment preceding the vowel segment. The spectrogram of the word /*t̪ɪkkʌ*/ uttered by an individual with CLP is shown in figure 3.

FIGURE 3: Spectrogram of class B glottal stop in medial position of word /*t̪ɪ**kk**ʌ*/.



Class B glottal stop production consists of closure duration, VOT, burst frequency and burst duration. The mean and standard deviation for acoustic parameters of Class B glottal stop such as closure duration, VOT, burst frequency and burst duration are described in table 3.

TABLE 3: Mean and standard deviation of closure duration, VOT, burst frequency and burst duration for Class B glottal stop

Parameters	Mean	Standard deviation

Closure duration (msec)	260.4	103.4
VOT (msec)	12.9	3.2
Burst frequency (Hz)	1953.8	335.9
Burst duration (msec)	7.3	1.8

The average closure duration of class B glottal stop is longer than that of closure duration of stop consonants produced normally in Tamil as specified by Savithri and Sridevi (2002, as cited in Savithri, 2004). The VOT of class B glottal stop is shorter than VOT of voiceless stop consonants as specified by Savithri and Sridevi (2002, as cited in Savithri, 2004). The duration of release burst for class B glottal stop is within the range of normal burst duration of the stop consonants as specified by Kent and Read (1992). The burst frequency of class B glottal stop is similar to the burst frequency of velar plosives (1500-4000 Hz) reported by Savithri (2004).

Acoustic Parameters of Class B Glottal Stop across Consonants

The mean value for acoustic parameters like closure duration, VOT, burst frequency and burst duration of class B glottal stops across the consonants are tabulated in table 4 showed a minimum difference across consonants.

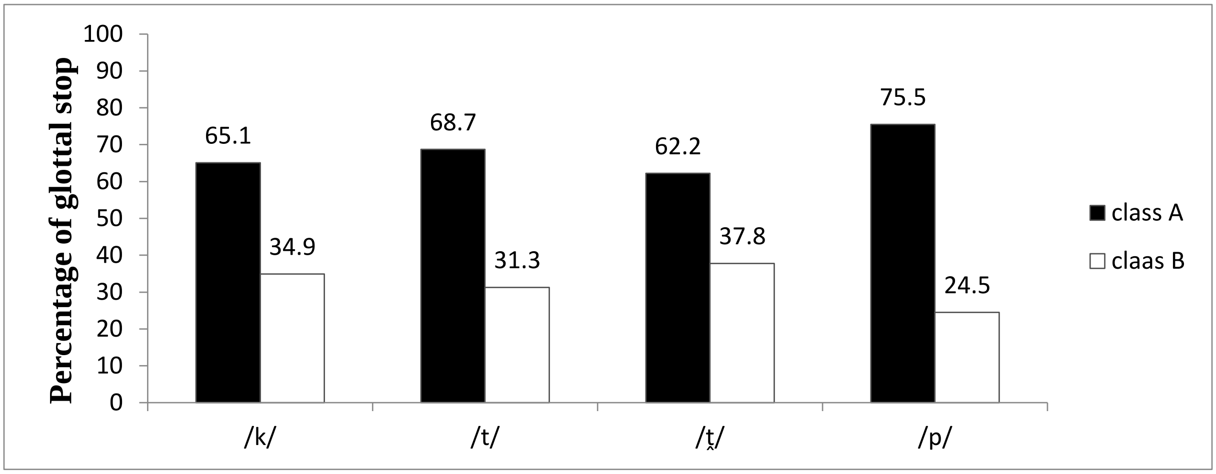
TABLE 4: Mean and standard deviation of acoustic parameters for class B glottal stop across consonants (/k/, /t/, /t̺/ and /p/).

Acoustic parameters	**Mean (msec)**				**Standard deviation**			
	/k/	/t/	/t̺/	/p/	/k/	/t/	/t̺/	/p/
Closure duration	249.8	275.6	252.4	275.5	97.7	107.5	108.3	76.6
VOT	13	13.2	12.5	12.4	3.4	3.06	3.2	3.9
Burst frequency	1900.4	1989	1979.2	1942.4	339.8	355.7	303.5	329.6
Burst Duration	7.5	7.2	7.1	7.7	2.4	1.2	1.6	1.2

Distribution of Class A and Class B Glottal Stop Errors across Stop Consonants

Total number of class A and class B glottal stops substituted for different stop consonants (/k/, /t/, /t̪/ / & /p/) were calculated and tabulated in figure 4.

Figure 4: Percentage of class A and class B glottal stop substituted for sounds /k/, /p/, /t/ and /t̪/



On an average, occurrence of class A glottal stop across consonants was 67.8% and class B glottal stop was 32.1%.These results show that children with CLP substitute more Class A glottal stop compared to Class B within and across consonants.

Discussion

The results from the perceptual judgement of glottal stops revealed a good reliability in judging glottal stops by the two judges. It might be attributed to the judge's experience and also the ability to correctly identify glottal stop errors. Evidence can be obtained from Gooch et al. (2001) that the judge's experience is an important factor in identifying compensatory errors in cleft palate speech. Both judges were native Tamil speakers; the effect of native language of the judge is crucial in the perceptual assessment of articulatory and resonatory patterns in cleft palate speech Cordero (2008). The frequency of occurrence of glottal stop was high for posterior sound /k/ than compared to anterior sounds. Earlier studies revealed that glottal stops are usually substituted for posterior sounds, especially back plosives compared to anterior sounds by speakers with cleft palate (Morris, 1973). A similar pattern was observed in this study.

In this study, acoustic analysis revealed class A and class B glottal stops are almost similar in the closure duration. In class A glottal stop, VOT and release burst were absent because of rapid transition to the voicing for the following vowel. In class B glottal stop, noise burst precedes the vowel segment. It is characterized by short lag VOT which is shorter than that of the voiceless stop consonants in Tamil language. Acoustic descriptions of glottal stop production in both classes are similar to that of the Type I and Type II glottal stop as described in the literature (Kawano et al,1991).

Savithri and Sridevi (2002, as cited in Savithri, 2004) found the closure duration of voiceless stop consonants in Tamil language to be 91msec. This study observed that closure durations of glottal stop in both classes are comparatively longer than those of the normal oral stops produced in Tamil. This could be due to higher articulatory resistance at the level of glottis during the production of oral stop consonants. Warren (1986) hypothesized that individuals with CLP exaggerate laryngeal gestures to compensate for a decrease in oral pressure and hyper-adduct their vocal folds in order to control airflow and provide the resistance needed for speech. This could be a possible reason for increased closure duration.

The VOT measures of class B glottal stop are shorter than the VOT of voiceless stop consonants in Tamil language specified by Savithri and Sridevi (2002, as cited in Savithri, 2004). The burst frequency of the class B glottal stop is similar to the burst frequency of velar plosives (1500-4000 Hz). This might be because the place of constriction for class B glottal stop is near to the velum. It may be assumed that Class B glottal stop produced by these subjects might be consequent to an attempt to approximate the correct production of oral stop consonants. They might follow the transition from class A glottal stop to class B glottal stop production during the course of therapy, i.e. place of articulation from glottal to the supraglottal level. In the current study, the subjects who participated had attended a few sessions of therapy or demonstration therapy to correct glottal errors. However, during the study only those individuals who demonstrated glottal stops were included. Though during perceptual analysis these tokens were perceived and agreed as glottal stops by the two judges, a different pattern was observed during the acoustic analysis.

Conclusions

This study has shown that glottal stop produced by subjects with CLP can be acoustically categorized into two types. Though perceptual analysis is the gold standard in articulatory assessment, the findings also highlight that acoustic analysis can be considered to augment regular perceptual analysis. The information from the study also emphasizes the need to consider acoustic information which can be used to evaluate the prognosis of the therapy for eliminating glottal stop. Measures obtained from acoustic analysis can be used to study outcome measures of therapy. These data have both theoretical and clinical implication in assessing the articulatory skill in Tamil-speaking individuals with CLP.

Presence of glottal stops could be identified through perceptual assessment. However, acoustic analysis provides more detailed information about various acoustic features of these glottal stops. From this study, the acoustic features of glottal stop provide information on distinguishing the glottal stop production into two distinct patterns underscoring the importance of acoustic analysis along with perceptual evaluation.

There have been no Tamil-language studies pertaining to acoustic analysis of glottal stop in individuals with CLP. The information from this study could be useful in monitoring the change in the production pattern during the therapy for elimination of glottal stop and it can be one of the future scopes of this study. These findings have both theoretical and clinical implication in assessing the articulatory skill in Tamil speaking individuals with CLP.

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