Research Article

Effect of Speech Therapy on Bilabial Production in Children with Repaired Cleft Lip and Palate

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Abstract

The present study is aimed to provide periodic documentation on the effects of speech therapy on temporal parameters in children with repaired cleft lip and palate (RCLP). The study consisted of two groups; the clinical group consisted of four participants with RCLP, and the control group consisted of ten typically developing children (TDC), between the age of 4-7.11 years with Kannada as their native language. The stimuli consisted of meaningful, picturable, age-appropriate Kannada words with bilabials in the initial position which were uttered by the participants. The type of error, presence/absence of burst, burst duration (BD), voice onset time (VOT) and word duration (WD) were analysed at baseline, after the therapy sessions and after the intervention. Articulation therapy was provided in two phases:perception training and production training. The temporal parameters considered in the present study were measured after every phase of the intervention from the clinical group and were compared to the mean value obtained from the control group. Perceptual assessment was also done by the speech language pathologist (SLP) which indicated an improvement in the production of the target words. Inter-rater reliability of the samples indicated a substantial agreement (k=0.69). Baseline assessment of the clinical group indicated absence of burst in 12 of the target utterances. In instances where the burst was present, BD and VOT were observed to be shorter compared to the control group. WD was found to be varying, indicating the presence of articulatory errors. With every assessment, changes in the temporal parameters were noted and compared with that of the control group. The analysis after intervention phase 4 indicated the presence of burst, changes in BD, VOT and increase in WD when compared to the TDC indicating a positive outcome of speech therapy. The results of the present study provide evidence that working on improving articulation brings about changes in the temporal parameters of speech, indicating an overall benefit from articulatory therapy in children with RCLP.

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INTRODUCTION

Velopharyngeal dysfunction (VPD) is one of the factors influencing speech development in children with repaired and/ or cleft lip and palate (R/CLP), resulting in articulatory errors. VPD impacts the production of vowels and consonants, resulting in hypernasality, nasal emission, nasal turbulence, and/or reduced intraoral air pressure on obstruent consonants (Kummer, 2013). The articulatory errors in R/CLP can be broadly classified into two types, one based on the structural abnormality, i.e., the obligatory errors (OE) and the other based on altered articulatory placement in response to the abnormal structure, i.e., compensatory articulation (CA) (Kummer, 2013). In addition, Henningsson et al. (2008) classified the consonant errors into the following categories: abnormal backing of the oral targets in post uvular, velar and glottal regions, nasal fricative, nasal consonants for oral pressure consonants, nasalised voiced pressure consonants, and weak oral consonants.

Despite the advances in surgical management, CA is reported to persist in R/CLP after surgery, thus, emphasising the need for speech therapy after surgery (Sankar, 2016; Bessell, et al., 2013). The studies by Mora et al. (2007) and Mora et al. (2009) opined that palatal surgery might result in scarring and tightening of the muscles, which might lead to shortening of the soft palate, and thereby VPD.

Safaiean et al. (2017) studied speech intelligibility in children with repaired cleft lip, or palate (RCL/P) who had not been referred for early intervention. The results of the study reported the presence of CA in more than half of the participants and OE in 40.6% of the participants, thereby affecting the speech intelligibility. Thus, from the above studies, it can be inferred that it is essential to improve the articulatory skills in individuals with cleft lip and palate

(CLP) followed by surgery.

Several studies have been carried out investigating the outcome of articulation therapy using different techniques. A study by Pamplona, Ysunza, and Espinosa (1999) compared the phonetic and phonologic approaches of articulation therapy in 29 children with cleft palate with CA. The participants ranged between 3 and 7 years with a complete unilateral cleft of both primary and secondary palate having VPD with CA. The first group received 'articulation intervention'; the second group was intervened using 'phonological approach'. The therapy lasted for one hour, twice a week, and continued until the CA was eliminated. The obtained pre and post-therapy samples were transcribed and analysed for the child's phonological system and the presence of CA. The results revealed that the total time required by the first group was between 14 and 46 months, while the second group needed 6 and 22 months, indicating that the phonological approach required a statistically significant shorter time duration compared to the articulatory approach, thus implying effectiveness of remediation strategies based on phonological principles during speech intervention.

Scherer, D'Antonio, and McGahey (2008) explored the effectiveness of a parent-implemented early intervention program for children with cleft palate between 14 and 36 months. The authors studied the effectiveness of focused stimulation for three months. Several speech and language measures were considered in the study. The speech measures considered were the percentage of glottal stops (GS), the number of true consonants in the phonetic inventory, and percentage consonant correct-Revised (PCC-R). The results indicated that early intervention improved parameters such as speech accuracy, sound inventory, and reduced the percentage of GS. The authors thus concluded that the parent-implemented program was useful in children with RCLP.

A review article by Bessell et al. (2013) evaluated 17 studies, which included control trials and observational studies mainly focusing on use of perceptual and spectral parameters to evaluate the progress of articulation intervention programs. The authors concluded by suggesting that there was no substantial evidence supporting any particular speech and language intervention using linguistic and/or traditional approaches. Further, the authors opined that more studies are required to provide adequate evidence on speech sound rehabilitation in children with RCL/P.

However, there are very few studies monitoring the individual prognosis of children with R/CLP. One such study was conducted by Derakhshandeh, et al. (2016). The study followed a single case experimental design that was carried out for over ten weeks. The authors aimed to study the effect of articulation therapy on articulatory errors of children with CLP with non-oral and passive cleft speech characteristics (PCSCs) in the presence of VPD. A combination of both motor phonetic and phonological approach was used in the study. The results indicated a decrease in non-oral cleft speech characteristics in five participants post-intervention. PCSCs were decreased in three participants, but increased in the other two. This was interpreted as intervention having changed the non-oral cleft speech characteristics to consonants produced within the oral cavity, but with passive characteristics affecting manner of production including weakness, nasalised plosives, and nasal realisations of plosives and fricatives. The results indicated a visible decrease in the errors for all five participants across the intervention phases.

Extensive studies have been done to describe the speech characteristics in children with CLP pre and post-surgery. Golding-Kushner (2001), Kummer (2013), and Peterson-Falzone, Hardin-Jones, and Karenll (2010) have proposed therapy techniques and strategies, based on their extensive experiences. However, the efficacy of the same has not been studied. Commonly, most of the articulatory assessments follow a perceptual evaluation. However, the subjective variability of the procedure necessitates the inclusion of an objective measure to assess the CA.

Acoustic analysis is one such objective measure that has gained importance to augment the subjective evaluation. Forner (1983) studied the uttered segment duration in 15 children with RCLP between 5 and 6 years of age. The stimuli used for the study were five nonsense syllables (consonants included- /p/, /t/, /k/, /t∫/, /s/). Closure duration (CD), voice onset time (VOT), vowel duration (VD), frication and affrication duration, and total duration (TD) were extracted using spectrograms and analysed. The results indicated that children with CLP have longer VOT, syllable duration, and total sentence duration compared to typically developing children (TDC). Further, among the children with cleft palate, it was observed that those who had low speech intelligibility scores had longer acoustic-phonetic segments than those with high intelligibility scores. Children with low speech intelligibility scores also showed a greater variability of segment duration and more frequent instances of aberrant timing patterns. Additionally, it was speculated that prolonged segmental duration might be a purposeful feature to compensate for damped sound energy.

Another study focusing on the temporal aspects was conducted by Sankar and Pushpavathi (2012),who investigated and compared the VD, CD, and TD in TDC and children with unoperated cleft palate. The VD, CD, and TD were found to be longer in children with cleft palate compared to the TDC.

Sankar, Pushpavathi, and Satish (2014) studied the changes in VOT in children with CLP in the pre and post-operative conditions and compared them with TDC in Kannada. The results revealed

the longest VOT was for the participants in the post-operative condition group followed by the pre-operative condition group, and then the control group. The study also highlighted the influence of surgical correction on the acoustic characteristics and the associated physiological changes in the oro-pharyngeal system.

A study conducted by Thomas, Subramaniyan, Savitha, and Nagarajan (2017) analysed the acoustic parameters of glottal stops in Tamil speaking children with unilateral CLP. The study included 18 participants between 8 and 13 years of age. A total of 1944 tokens generated by the participants were analysed out of which 843 tokens were identified as glottal stops for stop consonants. The acoustic analysis indicated two types of waveforms. In class A waveforms, only CD was identified. Class B waveforms indicated the presence of CD, VOT, BD and burst frequency. CD was longer than the normally produced CD, VOT was shorter than the VOT for voiceless stop consonants, BD was found to be within the normal BD range, and the burst frequency was similar to that of velar speech sounds. The authors suggested that acoustic analysis will be a helpful tool in assessment as well as in evaluation of prognosis during therapy in children with CLP.

There is an abundance of studies focusing on articulation therapy outcomes in RCLP using different therapy approaches. Studies related to the acoustic analysis in CLP has mainly focused on exploring the acoustic features of cleft palate speech. However, there are limited studies in monitoring the progress of articulation therapy through acoustic parameters. In view of this, the present study was designed to provide detailed documentation of the effects of articulation therapy on temporal parameters in children with RCLP at different time points during the intervention and comparing with a control group. Thus, the present study aimed to investigate the effect of articulation therapy on bilabial sounds in children with RCLP. The objectives of the study were to assess the temporal features in the production of bilabials in children with RCLP across the intervention phases and to compare them with TDC, and also to perceptually analyse and compare the articulatory errors for bilabials at two different time points during the intervention phase in RCLP.

METHODS

Participants

The study consisted of two groups of participants. Ten TDC, five in the 4-4.11 year age group and five in the 7-7.11 year age group, comprised the control group. The clinical group included four participants with RCLP. The participants in both groups were between the ages of 4-7.11 years with the median age of 6 years. The participants had Kannada (a Dravidian language spoken in the state of Karnataka, India) as their native language. The participants in the control group were screened for speech disorders using an assessment checklist for speech-language skills (Swapna et al., 2013). The sensory and motor development was assessed using the WHO Ten disability checklists (Singhi, et al., 2007) and those who passed these checklists were included in the study.

The participants included in the clinical group had age adequate receptive and expressive language levels, normal hearing threshold, having undergone cleft lip surgery and primary palatal surgery atleast before two years of age. The participants were screened for receptive and expressive language level using the Modified–Receptive and Expressive Language Test (M-RELT, Deepa, Shymala & Deepthi, 2014). The plastic surgeon confirmed the presence of VPD in the clinical group through visual inspection, and the orthodontist confirmed the absence of dental anomalies, hindering the production of bilabials in the participants of the clinical group. Speech sound disorder (SSD) of stop consonants in the clinical group, was diagnosed by the administration of Kannada Diagnostic Photo Articulation Test (KDPAT, Deepa & Savithri, 2010). They exhibited CA for production of bilabials. Participants with mild to moderate degree of hypernasality were considered in the present study. Participants with other associated neurological problems and structural anomalies were excluded. The participants who had previously attended therapy for a maximum of 30-40 sessions, which primarily focussed on language development, were considered in the present study. The study was explained to the caregivers of all the participants, following which written consent was obtained. Ethical clearance was obtained from the institutional review board. The details of the participants in the clinical and control groups are presented in Table 1.

As the participants in the clinical group exhibited SSD, they were given articulation therapy. Prior to articulation therapy, the participants were assessed again for articulatory errors. The stimuli were separate for assessment and therapy. As the temporal parameters were assessed in the present study, attention was given to the word structure. The words with the target consonant in three different vowel contexts i. e., /a/, /i/ and /u/ in the initial position were selected. The stimuli for assessment consisted of 6 words (CVCV, CVCVCV, and CVCCV) with /p/ and /b/ in initial position. For therapy, 30 words with /p/ and /b/ in the initial position were chosen and used during therapy to maintain consistency across the participants. All the words were meaningful, picturable and age-appropriate. The words were selected from KDPAT (Deepa & Savithri, 2010), Articulation drill book for cleft palate population (Prasad, 2011), Kannada Dictionary and the government prescribed Kannada textbook for primary school children. Picture stimuli were prepared for the selected words.

Table 1: Demographic details of the clinical group and control group

Group	Participant code	Gender	Age (years)	Type of cleft	Surgery details	
					Lip	Palate
Clinical group	P1	F	7.6	(R)UCLP	6 months	2 years
	P2	F	7.4	(R)BCLP	6 months	1 year
	P3	M	4.5	(R)UCLP	3.5 months	9 months
	P4	M	4.6	(R)BCLP	6 months	1 year
Control group	C1	F	7.9	NA	NA	NA
	C2	F	7.3	NA	NA	NA
	C3	M	7.8	NA	NA	NA
	C4	F	7.8	NA	NA	NA
	C5	F	7.2	NA	NA	NA
	C6	F	4.8	NA	NA	NA
	C7	M	4.6	NA	NA	NA
	C8	F	4.3	NA	NA	NA
	C9	M	4.6	NA	NA	NA
	C10	F	4.5	NA	NA	NA

Note: M- Male, F- Female, (R) UCLP- repaired unilateral cleft lip and palate, (R) BCLP repaired bilateral cleft lip and palate, NA- Not applicable

Data collection

The data collection was done individually for both the clinical and control groups. The participants were seated comfortably in a quiet room. Colour picture stimuli were presented by the investigator using Microsoft office PowerPoint (2013) on a laptop (Asus Vivobook 15) with a display screen of 15.6 inches. When the participants found it difficult to name the picture, the investigator produced the target utterance, and the participants were asked to repeat the words three times clearly with an interval of a minimum of 100 msec between each word. Once the child was able to repeat the target word, the next target was presented to the child. The repeated words were then audio recorded by placing the microphone (Mipro MM-107) 3cms away from the child's mouth using Praat software version 5.3.35 (Boersma & Weenink, 2012) on a personal computer. Out of three trials, based on visual inspection, the second repetition was considered for analysis as it was found to be more stable. The temporal parameters of the words produced by participants in the clinical group were compared with that of the corresponding words produced by participants in the control group.

Analyses

The speech samples obtained were subjected to acoustic analysis The temporal parameters analysed are as described below.

1. Presence or absence of burst- Spectrographic analysis was carried out to confirm the presence or absence of burst for the bilabial sounds.

2. Burst Duration (BD): Burst duration was measured as the time difference between the onset and offset of the articulatory release in a word-initial position. On the wideband bar type spectrogram, the cursor was placed at the point of onset of the burst, till the offset of burst and time difference was noted.

3. Voice onset time (VOT): It is the time difference between the release of a complete articulatory constriction and onset of the quasi-periodic vocal fold vibration in a word-initial stop consonant (Lisker& Abramson, 1964). On the wideband bar type spectrogram, VOT was measured as the time duration between the onset of burst and the onset of voicing depicted as voice bars on the baseline.

4. Word Duration (WD): It is the time difference between the onset and the offset of the target word. The word duration was measured by placing the cursor at the onset and offset of the word on the wideband bar type spectrogram.

The temporal parameters of all the words were analysed acoustically using Praat software version 5.3.35 (Boersma & Weenink, 2012). Each word was shown on a wideband bar type spectrogram with the pre-emphasis factor of "0.80". The size and bandwidth were set to 100 points and 160 Hz "hamming" window for analyses. The Wideband bar spectrogram was shown in monochrome (black and white) on a linear scale.

Perceptual analysis

Perceptual analysis was also considered in the present study as it is considered to be the gold standard method. The errors considered in the present study are detailed below:

1. **Glottal:** Atypical backing of oral sounds to post uvular place.

2. **Pharyngeal:** Atypical backing of oral sounds to post uvular place.

3. **Mid dorsum palatal stop :** Abnormal backing of oral sounds, but the place remains oral and produced as mid dorsum palatal sounds.

4. **Uvular:** Abnormal backing of oral sounds, but the place remains oral and produced as uvular.

5. **Velar:** Abnormal backing of oral sounds, but the place remains oral and produced as velar.

6. **Nasal consonants for oral pressure consonants:** A homorganic nasal consonant replaces the target stop consonant.

7. **Nasalized voiced pressure consonant:** The target stop consonant maintains its features but loses some or most of its oral quality. The voiced consonants are nasalized.

8. **Weak oral pressure consonant:** There is an overall loss of energy in the production of high-pressure consonants.

9. **Voicing errors:** A change in the voicing characteristic of the consonant.

The judges were asked to indicate the presence or absence of the above mentioned errors after listening to the sample. The result obtained from three judges were compared and in instances where two or more judges indicated the presence of the particular error, it was considered for further analysis. The speech samples used to ear train the judges were not considered in the final analysis.

The analysis was carried out by three SLPs, who had three years of clinical and research experience in CLP and acoustics. They were between 26 and 45 years of age. The judges were additionally trained for auditory perception and spectrographic inspection in three sessions of one hour each. The judges were given information about the temporal parameters of bilabial sounds using the samples from the control group. They were instructed to listen to the target words and inspect spectrographically using Praat software version 5.3.35. They were asked to consider all the parameters included in the study from the waveform using wideband bar type spectrogram as reference.

Therapeutic intervention procedure

The main goal of therapy was to eliminate/reduce error production and to provide the participants of the clinical group with appropriate instruction to learn the target bilabial oral productions. Prior to the commencement of therapy, the speech samples were perceptually analysed and the articulation therapy was formulated based on the strategies/ principles advocated by Golding-Kushner (2001), Kummer (2013), and Peterson-Falzone et al. (2010). Articulation therapy was provided by the investigator based on the principles of traditional articulation therapy. The articulation therapy was carried out in two phases, Phase I, and Phase II, focusing on perception and production training, respectively. Speech sounds for articulation therapy was considered based on the visibility of the phoneme (anterior sounds were considered first followed by the posterior sounds), voicing (voiceless phonemes were considered first), and the normal developmental pattern (KDPAT; Deepa & Savithri, 2010). Perception training included auditory discrimination of the error sound versus the correct sound. In instances where the child was unable to discriminate between the target phoneme and error phoneme, appropriate cues were provided to make the child understand the difference between the target and error sound. Place map was used to indicate the place of articulation of the target and error sounds. Modelling was carried out to make the child understand the activity. Further, inter and intra rater discrimination was carried out. When the child in the clinical group was able to discriminate the target versus error production, eight out of ten times, production training (phase II of therapy)was initiated.

Production training mainly focused on the phonetic placement approach, shaping of the target sound and regulating the airflow through the oral cavity. The investigator modelled the place of articulation of the target sound and indicated the same using place maps. Further, auditory, tactile, and visual cues were given to facilitate correct production. The instruction was given, keeping in mind the place of articulation of the target phoneme and the airflow through the oral cavity.

The first word produced with the target phoneme before the initiation of therapy in every session was considered for scoring. The number of correct responses for each word in every session was calculated. Once the participant in the clinical group achieved the target sound in the initial position, six out of ten times consistently, the next target phoneme was considered. Extensive home training was advised and the articulation drill material was given for practice at home. The parent/ caregiver was present during all therapy sessions to observe the therapist and clarification was provided if any. At the end of each session, the therapist explained the speech tasks and activities to be practised at home.

Research design

The study used a single-subject design with multiple baselines as listed below.

1. **Baseline (Assessment1- A1):** The perceptual and temporal parameters were analysed for six meaningful words before the initiation of therapy.

2. **Intervention:** The participants in the clinical group were provided with articulation therapy by the primary investigator. The therapy focused on the target phoneme in the initial position. Each session lasted for 45 minutes, three times a week.

3. **Intervention Phase 2- 4 (A2-A4):** Temporal parameters of the clinical group were extracted for the same phoneme after ten sessions (A2), 20 sessions (A3), and 30 sessions (A4) at the word-initial position and compared with the temporal parameters of the TDC. Additional perceptual assessment was carried out during A4. The same is depicted in figure 1.

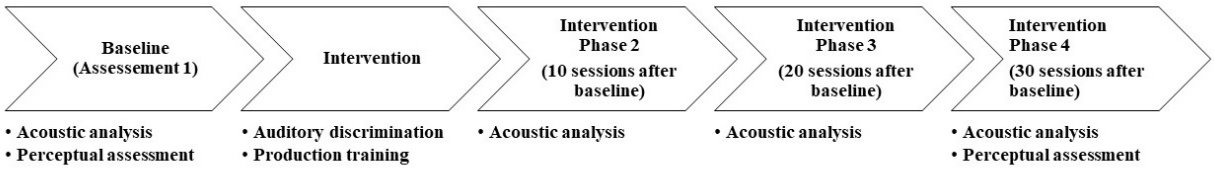

Figure 1: Research design followed in the present study

Data analysis and reliability

Three experienced SLPs, including the primary investigator, analysed the speech samples of the clinical group for the temporal parameters. Qualitative and quantitative analyses were carried out. To measure inter-rater reliability, the Kappa coefficient was calculated. The temporal parameters extracted from the speech sample of the control group were fed into SPSS software version 20, after which descriptive statistics were carried out.

RESULTS

The present study was aimed at analyzing errors in cleft palate speech and comparison of temporal parameters of speech in children with RCLP over the course of intervention with that of TDC. The inter-rater reliability of the ratings of the temporal parameters was evaluated based on the Kappa statistics. The results revealed substantial inter-rater reliability (k=0.69).

The participants of the clinical group underwent therapy for ten weeks in total. The variables were measured every tenth session to document the progress. Since there was variability across the clinical group, the results obtained from individual participants have been presented. The present study focussed on the progress of bilabial production, the results of which have been summarised under the following sections.

a. **Temporal features of bilabials in children with RCLP across therapy sessions in comparison with TDC.**

The participants in the clinical group exhibited a change in the temporal parameters across different time points of assessments. The progress of each participant w.r.t to the presence/ absence of burst, BD, VOT, and WD is presented in the section below.

The results of participant 1 (P1) is presented in table 2. During the baseline assessment of P1, the spectrographic analysis indicated the presence of burst in all the target productions. The BD was shorter compared to the mean BD of the control group. VOT was observed to be reduced for the voiceless bilabials, whereas it was observed to be similar to the mean values of the control group for voiced bilabials. WD was found to be shorter for /pi/ /pu/ and /bu/, longer for /ba/ and /bi/ and same for /pa/ during the baseline assessment, compared to the mean of the control group.

It was observed that, the burst was present for all productions over the four time points. There was a change in the BD, VOT, and WD across the different assessments as depicted in table 2. For /pa/, there was an increase in the BD and VOT with a dip during the A4. WD was found to be increased compared to the baseline assessment. The BD and WD for /pi/ was found to increase with a dip during A4, while VOT increased with the subsequent assessments. The BD, VOT and WD were found to increase with progress in time points for /pu/. For /ba/, BD and VOT was found to increase with a dip during A4; however, there was no consistent trend for WD. /bi/ and /bu/ showed an increase in BD with subsequent assessments. VOT for /bi/ was observed to increase with assessments, whereas the same was not observed for /bu/. A consistent increase was observed in the WD of /bi/, whereas /bu/ reported a sudden increase during A2 followed by a decrease in A3 and A4. During A4, the spectrographic analysis indicated the presence of burst for all the productions. Overall, the BD was observed to be higher than the mean BD of the TDC. VOT and WD were found to be consistently higher than the control group.

The results of the participant 2 (P2) are indicated in Table 3. During the baseline assessment, the spectrographic analysis indicated the absence of burst for all the target productions except /ba/. Consequently, BD and VOT could not be obtained for any of the target sounds except /ba/. Compared to the mean values of the control group, the BD and VOT of /ba/ were found to be shorter in P2, whereas WD was similar albeit manner variations.

On the whole, within the clinical group, during the A2 which was carried out after ten sessions of intervention, it was observed that the burst was present for all the productions except for /pi/ and /pu/. The BD, VOT, and WD increased across sessions. Overall, there was a difference in production from the baseline to A4, but a consistent pattern was not observed.

During A4, the spectrographic analysis indicated the presence of burst for all the productions. BD was

Table 2: BD, VOT, WD, and cleft type error of participant 1 (P1) and mean, SD and median values of the control group (7-7.11 years)for the bilabial place of articulation

Target Phoneme		P1				TDC		
		B	A2	A3	A4	Mean	SD	Median
/pa/	Burst	Present	Present	Present	Present	Present		
	BD (msec)	0.61	9.61	11.72	7.52	5.85	1.66	6.91
	VOT (msec)	1.40	81.34	31.01	34.11	13.65	3.17	14.20
	WD (msec)	451.61	580.05	501.13	589.43	426.34	59.92	409.14
/pi/	Burst	Absent	Present	Present	Present	Present		
	BD (msec)	0	5.91	14.27	5.70	5.41	1.29	5.43
	VOT (msec)	0	47.04	34.36	34.61	16.37	4.09	16.80
	WD (msec)	502.24	818.95	812.34	794.12	643.69	14.01	631.16
/pu/	Burst	Present	Present	Present	Present	Present		
	BD (msec)	1.62	1.79	2.14	6.66	6.34	1.22	5.89
	VOT (msec)	13.21	29.16	38.98	47.41	20.99	5.09	22.89
	WD (msec)	257.51	363.51	504.11	599.29	434.54	15.27	440.96
/ba/	Burst	Present	Present	Present	Present	Present		
	BD (msec)	3.21	4.38	7.64	4.76	4.42	1.33	4.14
	VOT (msec)	-79.12	-156.47	-145.35	-130.71	-71.22	12.3	76.89
	WD (msec)	699.92	625.51	604.25	615.71	503.89	34.46	520.17
/bi/	Burst	Present	Present	Present	Present	Present		
	BD (msec)	2.12	4.62	4.63	6.23	4.85	1.19	4.20
	VOT (msec)	-72.12	-152.52	-168.33	-160.70	-72.08	10.56	73.53
	WD (msec)	678.31	821.86	828.04	828.73	610.16	22.59	623.20
/bu/	Burst	Present	Present	Present	Present	Present		
	BD (msec)	0.12	4.62	2.72	6.23	3.83	0.59	3.62
	VOT (msec)	-61.5	-132.12	-129.25	-106.11	-58.90	5.99	57.36
	WD (msec)	445.71	1003.9	808.90	830.14	608.30	17.37	612.78

Note: B- Baseline, A2- Intervention phase 2, A3- Intervention phase 3, A4- Intervention phase 4, BD- Burst duration, VOT-Voice onset time WD-Word Duration.

observed to be similar to that of the mean value of the control group with minimal variations. VOT was found to be shorter for the voiceless and greater for the voiced bilabials compared to the mean of TDC. WD was found to be higher compared to the mean values of the control group.

The summary of findings of participant 3 (P3) is presented in Table 4, and the spectrographic baseline assessment indicated the presence of burst for /pi/, /pu/ and /ba/. The burst was absent for /pa/ and /bi/, while it was not analysed for /bu/ due to error (substitution of nasal sound for oral sound) in the target production. BD was either absent or lesser than the mean of the control group when present. There was no consistent pattern observed for VOT. The WD values were found to be lesser than the mean duration of the control group for the unvoiced sounds and higher than the control group for their voiced counterpart.

It was observed that the burst was present for all the productions during A2 except for /pa/ and /bi/. Due to the error in the production (substitution of nasal sound for oral sound), the burst was not determined for a few speech sounds. The BD was found to increase consistently with every time point for the voiced target sounds, whereas, variations were observed for the voiceless sounds. A dip in the VOT values was observed from A3 to A4 for the bilabials with minimal variation. WD was found to vary across /pi/,/pu/,/ba/,/bi/ and /bu/, whereas an increase was observed for /pa/.

Spectrographic analysis during A4 indicated the presence of burst for all the productions. In comparison with the control group, BD was similar, VOT was shorter for voiceless bilabials, but longer for voiced bilabials and WD was also found to be longer.

The analysis of the temporal parameters of participant 4 (P4) is indicated in Table 5 (page no. 65).

Table 3: BD, VOT, WD, and cleft type error of participant 2 (P2) and mean, SD and median values of the control group (7-7.11 years) for the bilabial place of articulation

Target Phoneme		P2				TDC		
		B	A2	A3	A4	Mean	SD	Media
/pa/	Burst	Absent	Present	Present	Present	Present		
	BD (msec)	0	3.81	2.89	6.10	5.85	1.66	6.91
	VOT (msec)	0	8.45	7.25	8.12	13.65	3.17	14.20
	WD (msec)	473.91	621.17	570.15	459.1	426.34	59.92	409.14
/pi/	Burst	Absent	Absent	Absent	Present	Present		
	BD (msec)	0	0	0	1.01	5.41	1.29	5.43
	VOT (msec)	0	0	0	6.10	16.37	4.09	16.80
	WD (msec)	502.24	986.53	1167.28	926.30	643.69	14.01	631.16
/pu/	Burst	Absent	Present	Present	Present	Present		
	BD (msec)	0	6.23	5.53	6.12	6.34	1.22	5.89
	VOT (msec)	0	40.92	33.63	18.10	20.99	5.09	22.89
	WD (msec)	520.31	623.31	537.57	623.30	434.54	15.27	440.96
/ba/	Burst	Present	Present	Present	Present	Present		
	BD (msec)	2.21	7.12	4.10	3.61	4.42	1.33	4.14
	VOT (msec)	39.05	-116.23	-178.64	-128.91	-71.22	12.3	76.89
	WD (msec)	539.91	541.51	733.47	541.51	503.89	34.46	520.17
/bi/	Burst	Absent	Absent	Absent	Present	Present		
	BD (msec)	0	0	0	5.21	4.85	1.19	4.20
	VOT (msec)	0	0	0	-183.51	-72.08	10.56	73.53
	WD (msec)	539.12	1223.21	818.32	1223.21	610.16	22.59	623.20
/bu/	Burst	Absent	Present	NA	Present	Present		
	BD (msec)	0	7.91	NA	2.69	3.83	0.59	3.62
	VOT (msec)	0	-86.27	NA	-64.32	-58.90	5.99	57.36
	WD (msec)	445.71	704.19	914.80	704.19	608.30	17.37	612.78

Note: B- Baseline, A2- Intervention phase 2, A3- Intervention phase 3, A4- Intervention phase 4, BD- Burst duration, VOT-Voice onset time WD-Word Duration.

During the baseline assessment, the burst, BD, and VOT were absent for all target productions except /ba/. Compared to the mean of the control group, the BD and VOT of /ba/ were found to be lesser. The majority of the WD values were found to be higher than the mean of the control group.

In A2, the presence of burst for unvoiced bilabials were not measured due to the errors in production. The BD and VOT increased across the different assessments. Similar results were not obtained for their voiced counterparts. WD was found to be longer compared to the baseline for the target words with /pu/, /ba/, and /bu/, but shorter for the other target words. There was a difference in the overall production, but a consistent pattern was not observed.

During A4, the spectrographic analysis indicated the presence of burst for all the productions. Further, in comparison with the control group, BD, VOT, as well as WD were found to be greater in P4.

b. **To perceptually analyse and compare the articulatory errors for bilabials at two different intervention stages in RCLP.**

The second objective of the study was to perceptually analyze speech of participants in the clinical group across the different intervention phases. A baseline assessment was carried out for a word-initial position for the clinical group; the results of which are depicted in Table 6 (page no. 65). Compilation of the results obtained from the judges, revealed that, among the perceptual parameters mentioned, only three types of errors were observed. Prior to the initiation of therapy, the errors observed included the presence of weak oral pressure consonant (WOPC), glottal stop (GS), and voicing errors (VE). However, the perceptual evaluation after A4, indicated

Table 4: BD, VOT, WD, and cleft type error of participant 3 (P3) and mean, SD and median values of the control group (4-4.11 years) for the bilabial place of articulation

Target phoneme		P3				TDC		
		B	A2	A3	A4	Mean	SD	Median
/pa/	Burst	Absent	Absent	Present	Present	Present		
	BD (msec)	0	0	1.81	5.43	4.60	2.07	4.56
	VOT (msec)	0	0	29.84	15.93	11.39	3.03	10.76
	WD (msec)	310.30	416.78	962.98	986.25	464.64	29.17	461.33
/pi/	Burst	Present	Present	Present	Present	Present		
	BD (msec)	2.6	0.21	6.19	4.40	4.95	1.54	5.70
	VOT (msec)	29.63	88.97	35.26	9.53	9.30	3.58	9.63
	WD (msec)	750.52	649.77	735.01	598.23	759.08	40.62	785.81
/pu/	Burst	Present	Present	Present	Present	Present		
	BD (msec)	3.59	0.24	2.25	6.25	5.60	0.80	5.72
	VOT (msec)	58.18	24.78	56.21	14.35	22.23	8.82	22.61
	WD (msec)	456.05	503.89	684.82	690.31	488.05	49.73	481.36
/ba/	Burst	Present	NA	Present	Present	Present		
	BD (msec)	3.18	NA	3.54	4.08	4.27	1.02	4.53
	VOT (msec)	-40.91	NA	-86.91	-159.74	-85.23	33.72	89.63
	WD (msec)	984.87	610.95	684.82	665.24	566.50	78.40	542.37
/bi/	Burst	Absent	Absent	Present	Present	Present		
	BD (msec)	0	0	2.09	3.33	3.47	0.63	3.27
	VOT (msec)	0	0	-155.71	-105.64	-63.19	17.73	66.03
	WD (msec)	798.65	710.95	740.30	888.37	636.44	46.03	625.23
/bu/	Burst	NA	NA	Present	Present	Present		
	BD (msec)	NA	NA	3.05	3.72	3.24	0.41	3.31
	VOT (msec)	NA	NA	-196.76	-99.74	-113.70	10.66	115.97
	WD (msec)	892.23	989.45	832.75	817.05	749.64	97.39	756.69

Note: B- Baseline, A2- Intervention phase 2, A3- Intervention phase 3, A4- Intervention phase 4, BD- Burst duration, VOT-Voice onset time WD-Word Duration.

the presence of only WOPC at large.

DISCUSSION

The current study aimed to analyse the temporal features such as burst, BD, VOT and WD in children with RCLP and to compare with the TDC. The results indicated a variation in the temporal parameters among the participants across the various time points.

The presence of burst and BD is one of the main features of a stop consonant, on spectrographic analysis. The spectrographic analysis in P1, P3 and P4 indicated the presence of burst for a few target words during the baseline assessment. The burst was absent in P2 and in some of the target words in P3 and P4. This could be attributed to incorrect place of articulation and reduced air flow in these participants. On the other hand, the presence of burst indicated that the participants maintained the correct place of articulation, but had a reduced/inadequate oral airflow. With repeated assessments, burst was evident for all the participants, thus indicating that they had achieved the correct place of articulation following therapy. This could be considered as a marker to confirm that the participants with RCLP had attained the forward place of articulation, required for the production of bilabials.

All the four participants in the clinical group exhibited reduced BD compared to the mean durationof the control group during the baseline. BD could not be calculated for 8 out of 12 voiceless sounds due to the absence of burst. In instances where BD were present, it was reduced. Similar findings were observed in their voiced counterparts. With the progress in therapy, an increase in the BD was observed in P1, P2 and P3, and these results may

Table 5: BD, VOT, WD, and cleft type error of participant 4 (P4) and mean, SD and median values of the control group (4-4.11 years) for the bilabial place of articulation

Target phoneme		P4				TDC		
		B	A2	A3	A4	Mean	SD	Mean
/pa/	Burst	Absent	Present	Present	Present	Present		
	BD (msec)	0	0.93	2.74	5.40	4.60	2.07	4.56
	VOT (msec)	0	12.43	80.57	48.94	11.39	3.03	10.76
	WD (msec)	718.62	696.46	540.39	584.01	464.64	29.17	461.33
/pi/	Burst	Absent	Present	Present	Present	Present		
	BD (msec)	0	0.13	4.35	7.05	4.95	1.54	5.70
	VOT (msec)	0	15.43	58.64	17.51	9.30	3.58	9.63
	WD (msec)	1023.45	952.83	805.01	1149.89	759.08	40.62	785.81
/pu/	Burst	Absent	Present	Present-M	Present	Present		
	BD (msec)	0	1.28	1.35	8.54	5.60	0.80	5.72
	VOT (msec)	0	95.96	55.33	65.44	22.23	8.82	22.61
	WD (msec)	729.94	952.83	459.65	540.00	488.05	49.73	481.36
/ba/	Burst	Present	NA	NA	Present	Present		
	BD (msec)	0.72	NA	NA	3 .11	4.27	1.02	4.53
	VOT (msec)	-53.50	NA	NA	-103.79	-85.23	33.72	89.63
	WD (msec)	708.53	1082.49	587.06	1031.26	566.50	78.40	542.37
/bi/	Burst	NA	Absent	NA	Present	Present		
	BD (msec)	NA	0	NA	4.97	3.47	0.63	3.27
	VOT (msec)	NA	0	NA	-74.56	-63.19	17.73	66.03
	WD (msec)	938.78	707.39	761.85	911.64	636.44	46.03	625.23
/bu/	Burst	Absent	NA	NA	Present	Present		
	BD (msec)	0	NA	NA	3.12	3.24	0.41	3.31
	VOT (msec)	0	NA	NA	-73.66	-113.70	10.66	115.97
	WD (msec)	997.43	1119.70	774.07	803.55	749.64	97.39	756.69

Note: B- Baseline, A2- intervention phase 2, A3- intervention phase 3, A4- intervention phase 4, BD- Burst duration, VOT-Voice onset time WD-Word Duration.

Table 6: Articulatory errors for bilabials for RCLP during baseline and intervention Phase 4

Participant	Target sound											
	/pa/		/pi/		/pu/		/ba/		/bi/		/bu/	
	Baseline	A4	Baseline	A4	Baseline	A4	Baseline	A4	Baseline	A4	Baseline	A4
P1	WOPC	NP	GS	NP	WOPC	NP	NP	NP	WOPC	NP	WOPC	NP
P2	WOPC	NP	GS	WOPC	GS	NP	WOPC	NP	GS	NP	WOPC	NP
P3	WOPC	NP	WOPC	NP	WOPC	NP	WOPC	NP	WOPC	NP	VE	NP
P4	GS	NP	GS	NP	GS	NP	WOPC	WOPC	VE	NP	GS	WOPC

Note: P1- participant 1, P2- participant 2, P3- participant 3, P4- participant 4, A4- intervention phase 4, WOPC- weak oral pressure consonant, GS- glottal stop, VE- voicing error- NP- normal production.

be attributed to the correct place of articulation and ability to regulate the oral airflow adequately. In P1, a sudden dip in the BD was observed during A4, which may be an attempt by the participant to stabilize the production over time. All the participants exhibited an increase in the VOT over the assessment time points with a decrease in the VOT values in some instances for voiceless target sounds. Voiced sounds reported a steady increase in the VOT values, which were longer compared to the mean values of the control group.This may be an attempt to stabilize the production with progress in implementing the principles of therapy. The findings of the present study are in coherence with the study conducted by Sankar (2016). Due to the presence of VPD, the results of the present study may have indicated shortened BD and VOT.

Palatal surgery is expected to have an effect on the elevation of velum during speech, as the surgical procedures are aimed to improve the functional aspects of velum, in addition to improving the thickness, length, and consistency of movement of velum. However, post-surgery, the individuals with RCLP may not be able to endure the same amount of intraoral pressure for a long time in the oral cavity leading to a shorter BD and VOT. With progress in therapy, the participants may be able to sustain the intraoral pressure, but due to the presence of VPD, there may be an air escape. In order to compensate, the participant may be taking more time to build the oral air pressure, thus leading to an increase in the BD and VOT duration.

Another parameter considered was the WD. It was observed that WD was equal to or more than the mean scores of the TDC during the baseline assessment. With progress in therapy, WD was found to increase in all four participants when compared to the baseline assessment. The minimal changes observed in the WD maybe an attempt to achieve the correct place of articulation by modifying the rate of speech. The results after A4 indicated a considerable increase in comparison to the mean of the control group.The results of the present study is in consensus with the previous studies wherein the WD was found to be greater in the RCLP group compared to the TDC group (Sankar 2016). WD was observed to vary consistently with subsequent assessments, which may be due to the prolongation of the segmental duration on purpose to compensate for damped sound energy (Forner, 1983). Prolongation of these features may be due to the participant's reduced speech rate, allowing the participant to make more precise contact with the articulators. The initial increase in the WD may be due to reduction in the rate of speech in order to find the correct place of articulation. With practice, the participants in the clinical group might have achieved the correct place of articulation and produced the word at their natural speaking rate, thus leading to a variation in duration across the time points.

In the present study, the therapeutic program focused on teaching the place of articulation, shaping the target sound, and regulating the airflow through the oral cavity. It was observed that most of the participants of the clinical group were able to achieve the target place of articulation by the end of the tenth session. Further, when the other target production was considered, the principles remained the same, reinforcing the ideology of regulating the airflow through the oral cavity. This may be one of the probable reasons for the improvement in the temporal features of the bilabial speech sounds.

The present study also investigated the perceptual parameters during the different intervention phases. During the baseline assessment, all four participants in the clinical group exhibited CA and a consequent variation in the temporal measures of the target sound compared to the mean scores of the control group. They also exhibited WOPC, followed by GS and voicing errors. The results of the present study support the findings of Sankar (2016) and Bessell et al. (2013), who report the persistence of articulatory errors in the speech of children with RCLP post-surgery with therapy. However, after the final assessment, the only error observed was WOPC. The altered word production can be attributed to speech therapy, which focused on the correct placement of the articulators along with correct regulation of the oral airflow.

The results of the present study provide evidence that working on articulation not only improves the target production as observed perceptually, but also has an impact on the temporal features of the particular speech sound such as the presence of burst, BD, VOT, and WD. The variation observed during the different stages clearly indicated that the participants were trying to alter their production, which may have led to a change in the temporal features. However, a consistent trend was not observed, which could be attributed to factors such as motivation of the subject, home training etc.

CONCLUSIONS

The participants of this study benefited from the intervention program, which focused on articulation placement and oral airflow. The perceptual evaluation indicated a positive change in the participant's production which was also evidenced in the multiple assessments across the intervention phases. BD, which was shorter during the baseline assessment, was found to be similar to the mean values of the TDC at the end of the assessments. VOT was found to be prolonged in all the participants as the assessments progressed. WD was found to be to consistently prolonged compared to the control group. The change in the temporal parameter, WD implied that the participants achieved the correct place of articulation, thus increasing the accuracy of production of the error sound. Hence, WD poses to be one of

the essential correlates in understanding the prognosis of cleft palate speech. Overall, the findings support that speech intervention program used in the present study for children with RCLP brings about changes in temporal features of speech due to changes in articulation.

However, there were a few limitations of the study. One of the main limitations was the number of participants. Finding the appropriate participants according to the inclusion and exclusion criteria was challenging. Many participants who fulfilled the criteria, did not attend therapy due to the caregiver's unwillingness to travel the long distance involved in reaching the therapy center. The second limitation was that the expert assessed the VP function through visualization. Direct investigations of VP function would have given a better perspective in understanding how the perceptual changes in speech correlated with changes in the VP mechanism.

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