

Vowel Productions in Malayalam Speaking Toddlers with Repaired Cleft Palate and /or Lip

Manju Subrahmanian¹, M. Pushpavathi²

¹Department of Audiology and Speech Language Pathology, National Institute of Speech and Hearing, Thiruvananthapuram,

²Department of Speech Language Pathology, All India Institute of Speech and Hearing, Manasagangothri, Mysore

Corresponding Author: Manju Subrahmanian

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ABSTRACT

Introduction: Cleft palate and /or lip is a congenital orofacial anomaly affecting speech production skills. The current study investigates vowel production in toddlers with repaired cleft palate and /or lip (RCP±L). The number and type of vowels in terms of tongue height and tongue advancement were computed from the speech sample extracted. In toddlers with RCP±L, the frequency of nasalized vowels was computed.

Method: A 30-minute mother-child interaction video was used for the extraction of speech samples for investigating vowel productions. Vowel productions of five 30–36-month-old toddlers with typical development (TD) were compared with the vowel productions of five 30–36-month-old toddlers with RCP±L.

Results: Toddlers with RCP±L were found to have significantly lesser productions of close-mid, high (close), front, and back vowels in comparison to toddlers with TD. Toddlers with RCP±L were also found to exhibit nasalization of vowels.

Conclusion: Quantity and quality of vowel productions are affected in toddlers with RCP±L, ascertaining the need for early intervention.

Keywords: Vowel production, toddlers, repaired cleft palate and /or lip, nasalized vowels, tongue height, tongue advancement, Malayalam

INTRODUCTION

Constraints either in the structures or functioning of respiratory, phonatory, articulatory, resonatory, and nervous systems would adversely affect speech production skills. Cleft lip and/or palate (CL±P), is a craniofacial anomaly with an overall incidence of approximately 1 in 700 live births [1], leading to altered resonance characteristics and deviant articulatory patterns [2,3,4,5] in children. The deviant production begins during the pre- speech period; reflected as a preference to the usage of vowels, speech sounds produced posterior to the velopharyngeal port, and nasal consonants [5,6,7,8,9]. Vowels are sonorants

that require less oral pressure [10] and are produced more frequently than consonants by toddlers with CL±P in contrast to toddlers with typical development (TD). A limited variety of vowel productions and more isolated vowel syllable productions are prominent in toddlers with repaired cleft palate (RCP) [11]. Even in word formation, vowel usage is more prominent [10]. Among the vowels, 11- 18-month Tamil speaking toddlers with unrepaired cleft of lip and palate (URCLP) have a higher occurrence of back vowels, and open and open mid vowels in contrast to toddlers with TD who have more front, central and close vowel productions [9]. During the vocalization and

verbalization phase, Tamil speaking toddlers with repaired cleft lip and palate (RCLP) produced central vowels more frequently than front and back vowels [12]. But by the preschool period (three to five years of age), Kannada speaking children with RCLP did not exhibit differences in vowel productions in comparison to children with TD [13].

Consistent velopharyngeal closure is necessary for the production of vowels with appropriate resonance. In children with typical development (TD), velopharyngeal closure for vowels has been reported to be 93% and 98% for CV and VCV syllables by Eshghi, Vallino, Baylis et al, [14]. For isolated vowels, consistent velar closure may not be produced due to a lack of oral pressure. But vowels may be produced with consistent velar closure in the presence of adjacent oral stops with greater oral pressure that might aid in velar elevation and tighter closure. Infants with typical development (TD) may produce vowels with consistent velar closure by at least 12 months of age. Meanwhile, in children with repaired cleft palate (RCP), consistent velopharyngeal closure was attained for vowels at 14 months of age, three to four months post palatal repair [15]. This was postulated to be associated with the establishment of oro-motor movements and acoustic output, growth spurt of soft palate [14], adenoids [16,17], and healing rate of soft palate [15]. Inconsistent or inadequate velopharyngeal closure during speech production causes nasalization.

Nasality is more evident on phonemes that need more intra-oral breath pressure as it creates demands on the velopharyngeal port such as higher points of posterior pharyngeal wall/velar contacts, tighter velopharyngeal seals, and greater velar excursion. Amongst the vowels, nasality is more on high rather than low vowels [18,19]. More nasality is perceived in high front vowels as they might be challenging for the velopharyngeal sphincter [20], attributable to the coronal closure pattern created by blocking the oral airflow during its production [21]. This

would also lead to an increase in compensatory articulations [20].

NEED OF THE STUDY: Though vowels are produced more frequently than consonants by toddlers with cleft lip and palate, differences have been reported in comparison with vowel productions by toddlers with TD. Differences are evidenced in terms of the frequency of the types of vowels used and also their resonances. The vowel inventory in Malayalam speaking children with TD has been reported by Sunny & Kumaraswamy [22] and among adults with TD by Sreedevi & Irfana [21] and Agnes & Roy [23]. There are 11 monophthongs in Malayalam, a Dravidian language spoken by over 34 million people in Kerala, a state in South India. Mastery of vowels has been reported in Malayalam speaking children before the age of three years [22] and hence, research regarding the acquisition and accuracy of vowel productions in Malayalam speaking children with cleft palate and/or lip (CP±L) would be beneficial. Nasalization of vowels has been reported in Tamil speaking toddlers with URCLP by Hariharan [12] and RCLP by Sreedhanya, Nagarajan & Hariharan [9]. The impact of nasality on vowel production is considered for rating the degree of hypernasality in individuals with cleft palate [24]. Context of vowel production plays a crucial role and environments with pressure consonants have been reported to be challenging for individuals with cleft lip and palate, leading to nasalization of vowels. Malayalam has unaspirated-aspirated and voiceless-voiced counterparts of stop consonants and voiced-voiceless fricatives; thereby posing challenges for individuals with CP±L to attain age-appropriate articulation skills.

AIM: Thus, the current study aimed to investigate vowel production in Malayalam speaking toddlers (30-36 months) with repaired cleft palate and/or lip (RCP±L) in comparison with toddlers with typical development (TD).

OBJECTIVES:

- 1) To investigate the number and type of vowels in terms of tongue height in toddlers with TD.
- 2) To investigate the number and type of vowels in terms of tongue height in toddlers with RCP±L.
- 3) To compare the number and type of vowels in terms of tongue height between toddlers with RCP±L and toddlers with TD.
- 4) To investigate the number and type of vowels in terms of tongue advancement in toddlers with TD.
- 5) To investigate the number and type of vowels in terms of tongue advancement in toddlers with RCP±L
- 6) To compare the number and type of vowels in terms of tongue advancement between toddlers with RCP±L and toddlers with TD

MATERIALS & METHODS

The current study is a cross-sectional study, employing a standard group comparison design. The vowel production of five toddlers with RCP±L was compared with five toddlers with TD.

The participants of this study were five toddlers with RCP±L and five toddlers with

TD. The toddlers with RCP±L were recruited from the cleft/ craniofacial clinic of the National Institute of Speech and Hearing, Thiruvananthapuram, Kerala, and St. Thomas Hospital, Malakkara, Kerala. The toddlers with TD were recruited using convenient sampling. All of the toddlers fulfilled the inclusion criteria of being native Malayalam speakers and belonging to low-middle or high-middle socio-economic status (as evaluated using a readapted version for 2009: NIMH socio-economic status scale). The minimal parental education was tenth grade. All the toddlers had adequate motor development skills (as measured using the Trivandrum Developmental Screening Checklist (TDSC) [25]) with no reports of sensorineural hearing loss and no history of more than two episodes of middle ear infections in a year. There were two participants with repaired cleft lip and palate and three participants with repaired cleft palate.

The mean age of repair of the cleft lip was 2.5 months of age and the mean age of repair of the cleft palate was 10.6 months of age. None of them had been enrolled in speech therapy sessions.

Table 1. Demographic details of the subjects

Group	Subjects	Age (in months)	Gender	Oral peripheral mechanism status	Age at surgical repair (in months)	
					Lips	Palate
Typical development	TD 01	35	Female	Typical	NA	NA
	TD 02	35	Female	Typical		
	TD 03	30	Female	Typical		
	TD 04	35	Female	Typical		
	TD 05	32	Female	Typical		
Repaired cleft palate and /or lip (RCP±L)	RCP±L 01	30	Male	Cleft lip and palate	2	8
	RCP±L 02	35	Female	Cleft palate	NA	12
	RCP±L 03	30	Male	Cleft palate	NA	11
	RCP±L 04	35	Male	Cleft lip and palate	3	10
	RCP±L 05	31	Male	Cleft palate	NA	12

PROCEDURE:

Informed consent was obtained from all the participants. A detailed case history of their demographic and clinical details was collected in a case history room. TDSC was then administered by observing the child perform the motor tasks and also confirming the information from the parents. Then the

mother and the child were shifted to a quiet room in the clinical department for extracting the speech sample.

A 30-minute mother-child interaction was video recorded using a Sony Handycam HDR -CX 405 to extract the speech features. The camera was mounted on a tripod stand placed at a distance of eight meters away

from the mother and the child, to enable visibility of the area under observation and also to avoid distraction for the toddler. To ensure a good signal-to-noise ratio, the recording was carried out in a sound-treated room at the National Institute of Speech and Hearing, Thiruvananthapuram, Kerala, or a speech therapeutic console at St. Thomas Hospital, Malakkara, Kerala. The toddler and the mother were made to sit on a mat spread on the floor to create a natural play setting, reduce anxiety, and maximize their communication. The mother was instructed to ensure the labeling of all the toys provided during the session using confrontation naming/imitation.

To elicit the speech sample, a total of 24 toys representing the phonetic inventory to be acquired by three years of age (as stated in the Malayalam Articulation Test-Revised [26]) were provided to the mother and child to have a natural play session. Two distractor toys such as blocks and a pull-along toy were also used during the session. All the toys were validated for their color, texture, and size by three Montessori-trained teachers with a minimum working experience of three years in a kindergarten school. All the toys had obtained a score of greater than 80% during validation, and thus they were used for eliciting speech samples during the session. Before each recording, sanitization of all the toys was carried out. All the toys and the mat were cleaned with a mild soap solution, followed by plain water, and then sanitized using an ultraviolet rod.

The video recording obtained was then saved to a hard disk via laptop and saved into a password-protected folder. The speech samples (vowels, diphthongs, singleton consonants, geminate consonants, and blends) were then transcribed using International Phonetic Association (IPA) symbols 2021 and the symbols in the Malayalam IPA help page on English Wikipedia. The transcribed speech samples were then entered into a Microsoft Excel sheet for analysis. The number of speech sounds was then calculated and the scores were subjected to statistical analysis.

STATISTICAL ANALYSIS

Analysis

The analyzed vowel productions have been grouped for toddlers with TD and toddlers with RCP±L. All the toddlers had exhibited phonological errors or developmental errors and they have been included in the phonetic inventory and labeled as true productions (TP). The total number of vowels produced has been labeled under a total number of vowel productions (TNP). In toddlers with RCP±L, the nasalization of vowels has been labeled as cleft speech characteristics (CSCs), and their frequency of productions were also analyzed.

From the scores calculated for vowel productions (in terms of tongue height and tongue advancement), the frequency (percentage) of occurrence has been calculated for each subject. The frequency of true vowel productions between the groups was compared using the Mann Whitney U test.

Table 2. Vowel classification in Malayalam

Tongue position		Vowel
Tongue height	High (close)	/i/, /u/
	Close mid	/e/, /o/
	Open mid	/ə/
	Low (open)	/a/
Tongue advancement	Front	/i/, /e/
	Central	/a/, /ə/
	Back	/u/, /o/

RESULT

The total number of utterances of the toddlers in both groups was analyzed. The speech sound characteristics of the toddlers were extracted from the 30-minute video recording of the mother-child interaction. Analysis of the total speech sample revealed that there was no significant difference ($z = -1.358, p = 0.222$) between the total number of utterances produced by toddlers with TD (Mean = 522.6) and the total number of utterances produced by toddlers with RCP±L (Mean = 325).

It was found (as depicted in Figure 1) that in the utterances produced, the phonetic repertoire of toddlers with TD had a greater frequency of consonant productions (51.34%) than vowels (48.66%). Meanwhile, toddlers with RCP±L had a greater frequency

of vowel productions (56.28 %) than consonants (43.72 %) in their phonetic repertoire. CSCs (nasalized vowels, nasalized consonants, nasal air emission

accompanying pressure consonants, velar stops, glottal stops, and pharyngeal fricatives) were evidenced in the speech sound productions of toddlers with RCP±L.

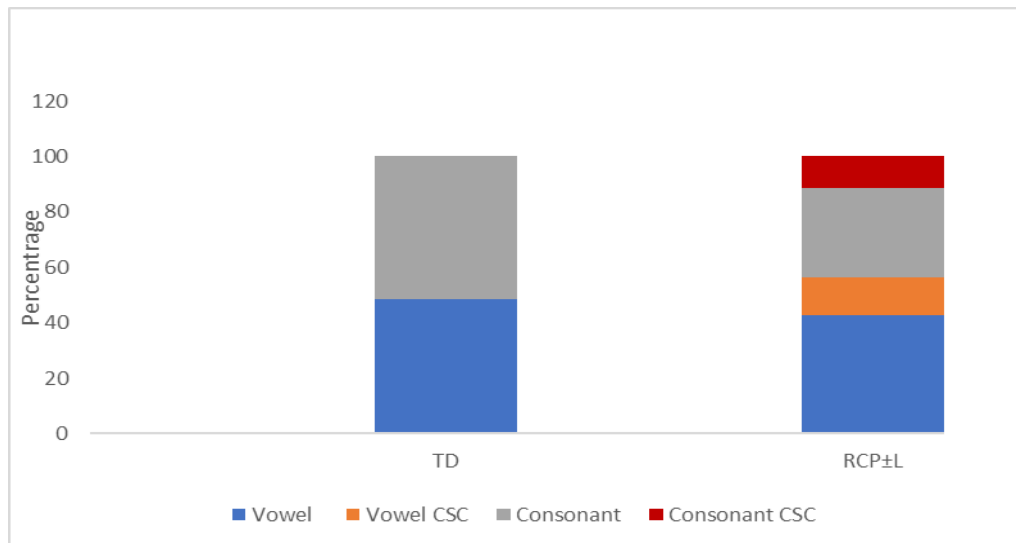


Figure 1. Percentage of vowels and consonants produced by toddlers with TD and toddlers with RCP±L. Note: CSC- Cleft Speech Characteristic

In the current study, vowel productions in terms of tongue height and tongue advancement produced by toddlers with TD and RCP±L were analyzed and compared. CSCs evidenced by toddlers with RCP±L were also analyzed.

Vowel productions in terms of tongue height

Number and type of vowels in terms of tongue height (high (close), close-mid, open mid, low (open) vowels) in Malayalam speaking toddlers with TD

Analysis of vowel productions in toddlers with TD (Table 3) revealed individual variations in terms of a total number of

productions as well as the frequency of productions of high (close), close-mid, open-mid, and low (open) Malayalam vowels. Quantitative analysis revealed that, out of the five participants, the total number of vowel productions (TNP) was found to be highest for participant TD 03, followed by TD 01, TD 04, and TD 02. However, TD 05 had the lowest number of vowel productions. All the toddlers, except TD 01 produced the low (open) vowel /a/ most frequently. TD 01 had the highest frequency of Malayalam close-mid vowels /e/ and /o/ productions. The lowest frequency of productions was evidenced for the open-mid vowel /ə/.

Table 3. Percentage of vowel productions (in terms of tongue height) in Malayalam speaking toddlers with typical development

Subject	TNP	High (close)	Close mid	Open mid	Low (open)
TD 01	1146	28.01	30.59	11.26	30.14
TD 02	905	28.25	19.47	9.23	43.05
TD 03	1672	28.17	24.44	12.01	35.38
TD 04	934	26.32	27.42	14.87	31.39
TD 05	431	24.35	21.04	15.60	39.01

*Note. TD – Typical development, TNP- Total number of vowel productions

Number and type of vowels in terms of tongue height (high (close), close-mid, open mid, low (open) vowels) in

Malayalam speaking toddlers with RCP±L

Analysis of vowel productions in toddlers with RCP±L (Table 4) revealed individual

variations in terms of a total number of productions as well as the frequency of productions of high (close), close-mid, open mid, and low (open) Malayalam vowels. Quantitative analysis revealed that out of the five toddlers, RCP±L 05 had the highest TNP followed by RCP±L 02, RCP±L 04, and RCP±L 03. However, RCP±L 01 had the lowest TNP. All the toddlers produced the low (open) vowel /a/ most frequently. All the toddlers except RCP±L 03 produced open-

mid vowel /ə/ least frequently. On qualitative analysis of the speech sample extracted, toddlers with RCP±L exhibited nasalization of vowels (cleft speech characteristics). The highest frequency of nasalization was exhibited by subjects RCP±L 04 and RCP±L 05, for the most frequently produced low (open) vowel /a/. RCP±L 05 consistently exhibited nasalization of all the vowels. RCP±L 01 had nasalization of the close-mid vowels /e/ and /o/.

Table 4. Percentage of vowel productions (in terms of tongue height) in Malayalam speaking toddlers with RCP±L

Subject	TNP	High			Close mid			Open mid			Low		
		TP	CSC	Total	TP	CSC	Total	TP	CSC	Total	TP	CSC	Total
RCP±L 01	173	9.20	0.00	9.20	17.24	1.72	18.97	1.15	0.00	1.15	70.69	0.00	70.69
RCP±L 02	502	26.17	0.00	26.17	17.24	0.00	17.24	16.02	0.00	16.02	40.57	0.00	40.57
RCP±L 03	309	10.07	0.00	10.07	9.40	0.00	9.40	11.74	0.00	11.74	68.79	0.00	68.79
RCP±L 04	355	10.45	0.00	10.45	13.41	2.27	15.68	2.95	0.00	2.95	51.59	19.32	70.91
RCP±L 05	1108	12.20	9.96	22.16	11.41	8.03	19.44	10.99	0.24	11.23	27.84	19.32	47.16

*Note. RCP±L- Repaired cleft palate and/or lip, TNP- Total number of vowel productions, TP – True productions, CSC- Cleft speech characteristics

Comparison of number and type of vowels in terms of tongue height (high (close), close-mid, open mid, low (open) vowels) between Malayalam speaking toddlers with TD and toddlers with RCP±L

A comparison of the frequency of vowel productions in terms of tongue height between toddlers with TD and RCP±L is depicted in Figure 2. Quantitative analysis revealed that toddlers with RCP±L had lesser TNP than toddlers with TD. Toddlers with TD and toddlers with RCP±L evidenced individual variations. All the toddlers produced the low (open) vowel /a/ most

frequently and the open mid vowel /ə/ least frequently. Low (open) vowel /a/ was produced more frequently by toddlers with RCP±L, meanwhile high (close), close-mid, and open mid vowels were produced more frequently by toddlers with TD. On qualitative analysis, nasalization (cleft speech characteristics- CSC) was observed during the production of all the vowel categories.

It was also noted that the toddlers with TD and RCP±L had more frequency of lax vowel productions (/a/, /i/, /u/, /e/, /o/) than tense vowel productions (/a:/, /i:/, /e:/, /o:/, /u:/).

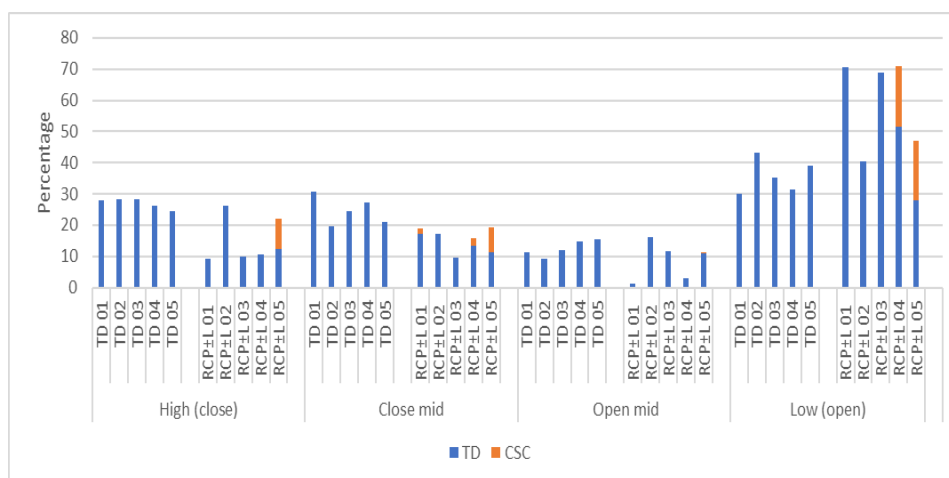


Figure 1. Comparison of vowel productions (in terms of tongue height) between Malayalam speaking toddlers with TD and toddlers with RCP±L

*Note. TD – Typical development, RCP±L- Repaired cleft palate and /or lip, TP – True productions, CSC- Cleft speech characteristic

Results of the Mann- Whitney U test (Table 5) comparing the frequency of true productions revealed that toddlers with RCP±L had a significantly lower frequency of high (close) (Z- -2.402, p = 0.016) and close mid (Z - -0.940, p = 0.008) vowel productions than toddlers with TD.

Table 5. Results of Mann Whitney U test for vowel production (classified according to tongue height) between Malayalam speaking toddlers with TD and RCP±L

		/Z/	p-value
Vowel (True productions)	High (close)	-2.402	0.016*
	Close mid	-2.619	0.008*
	Open mid	-0.940	0.421
	Low (open)	-1.358	0.22

*Note. p ≤ 0.05

Vowel productions in terms of tongue advancement

Number and type of vowels in terms of tongue advancement (front, central and back vowels) in Malayalam speaking toddlers with TD

Analysis of vowel productions in toddlers with TD (Table 6) revealed individual variations in terms of the total number of productions as well as the frequency of productions of front, central, and back Malayalam vowels. Quantitative analysis revealed that all the toddlers except TD 01 produced the Malayalam central vowels /a/ and /ə/ most frequently, with the highest frequency for /a/. All toddlers with TD produced back vowels /u/ and /o/ least frequently.

Table 6. Percentage of vowel productions (in terms of tongue advancement) in Malayalam speaking toddlers with typical development

Subject	Front	Central	Back
TD 01	43.71	41.40	14.89
TD 02	33.26	52.28	14.46
TD 03	34.59	47.39	18.02
TD 04	38.99	46.26	14.76
TD 05	31.91	54.61	13.48

*Note. TD – Typical development, TNP- Total number of vowel productions

Number and type of vowels in terms of tongue advancement (central, front and back vowels) in Malayalam speaking toddlers with RCP±L

Analysis of vowel productions in toddlers with RCP±L (Table 7) revealed individual variations in terms of the total number of productions as well as the frequency of productions of front, central, and back Malayalam vowels. Quantitative analysis revealed that all the toddlers with RCP±L produced central vowels /a/ and /ə/ most frequently, with the highest frequency for /a/. All the toddlers except RCP±L 03 produced back vowels /u/ and /o/ least frequently. On qualitative analysis of the speech sample extracted, toddlers with RCP±L exhibited nasalization of vowels (cleft speech characteristic). The highest frequency of nasalization was exhibited by subjects RCP±L 04 and RCP±L 05, for the most frequently produced central vowels. RCP±L 05 consistently exhibited nasalization of all the vowels. RCP±L 01 had exhibited nasalization of the back vowels /u/ and /o/.

Table 7. Percentage of vowel productions (in terms of tongue advancement) in Malayalam speaking toddlers with RCP±L

Subject	Front			Central			Back		
	TP	CSC	Total	TP	CSC	Total	TP	CSC	Total
RCP±L 01	21.84	0.00	21.84	71.84	0.00	71.84	4.60	1.72	6.32
RCP±L 02	30.43	0.00	30.43	56.59	0.00	56.59	12.98	0.00	12.98
RCP±L 03	8.39	0.00	8.39	80.54	0.00	80.54	11.07	0.00	11.07
RCP±L 04	12.50	0.68	13.18	54.55	19.32	73.87	11.36	1.59	12.95
RCP±L 05	15.04	12.86	27.9	38.83	19.57	58.4	8.57	5.13	13.7

*Note. RCP±L- Repaired cleft palate and/or lip, TNP- Total number of vowel productions, TP – True productions, CSC- Cleft speech characteristic

Comparison of number and type of vowels in terms of tongue advancement (front, central, and back vowels) between Malayalam speaking toddlers with TD and toddlers with RCP±L

A comparison of the frequency of vowel productions in terms of tongue advancement between toddlers with TD and RCP±L is

depicted in Figure 3. Quantitative analysis revealed that toddlers with RCP±L had lesser TNP than toddlers with TD. Toddlers with TD and toddlers with RCP±L evidenced individual variations. All the toddlers produced central vowels /a/ and /ə/ most frequently (with the highest frequency for /a/) and back vowels /u/ and /o/ least

frequently. Central vowels were produced more frequently by toddlers with RCP±L meanwhile, front and back vowels were produced more frequently by toddlers with TD. On qualitative analysis, nasalization (cleft speech characteristics- CSC) was

observed during the production of all the vowel categories.

It was also noted that the toddlers with TD and RCP±L had more frequency of lax vowel productions (/a/, /i/, /u/, /e/, /o/) than tense vowel productions (/a:/, /i:/, /e:/, /o:/, /u:/).

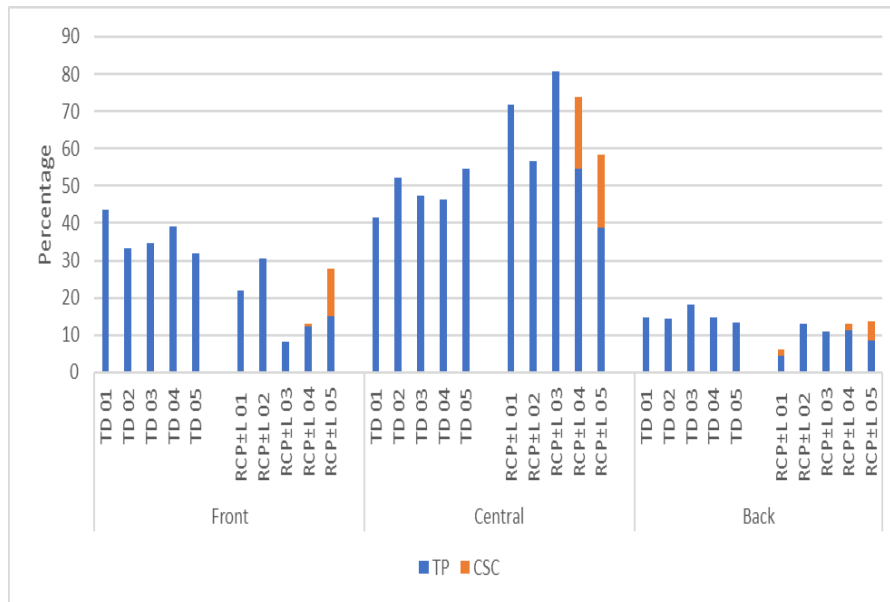


Figure 2. Comparison of vowel productions (in terms of tongue advancement) between Malayalam speaking toddlers with TD and toddlers with RCP±L

*Note. TD – Typical development, RCP±L- Repaired cleft palate and /or lip, TP – True productions, CSC- Cleft speech characteristics

Results of the Mann- Whitney U test (Table 8) comparing the frequency of true productions revealed that toddlers with RCP±L had a significantly lower frequency of front (z - -2.611, p- 0.008) and back (z - -2.611, p- 0.008) vowel productions than toddlers with TD.

Table 8. Results of Mann Whitney U test for vowel production (classified according to tongue advancement) between Malayalam speaking toddlers with TD and RCP±L

Vowel (True productions)	/Z/		p value
	Front	Back	
	-2.611	-2.611	0.008*
	-1.358	-1.358	0.222

*Note. p ≤ 0.05

DISCUSSION

The current study investigated vowel productions in Malayalam speaking toddlers (aged 30-36 months of age) with repaired cleft palate and /or lip and in toddlers with TD. The frequency of vowel productions by toddlers with TD and RCP±L was compared. Cleft speech characteristics (CSCs) exhibited by toddlers with RCP±L were also analyzed.

In the current study, toddlers with RCP±L had a greater frequency of vowel productions than consonant productions in contrast to the findings in toddlers with TD who had a greater frequency of consonant productions. Greater frequency of vowel productions has been reported in children with cleft lip and/or palate by O’Gara & Logemann [7], Chapman[8], Sreedhanya, Hariharan & Nagarajan[9], and Williadsen & Enemark [27]. These findings can be attributed to the findings of Raphael, Borden & Harris [28] that constrictions made during the production of vowels were less complex than for the non-resonant consonants such as stops, fricatives, and affricates.

Vowel productions in toddlers

Analysis of the vowel productions by each toddler revealed individual variations between the participants in terms of the total number of vowel productions (TNP) and the frequency of low, open mid, close-mid, and

high vowels. These individual variations can be accounted for by the variations in the quantity and variety of verbal response elicitation methods implemented and the reinforcements provided by the mothers during the session.

Though the same toys were used for the extraction of speech sound inventory, TD 03 and RCP±L 05 had the highest TNP, whereas TD 05 and RCP±L 01 had the lowest TNP. The use of multiple modes of response elicitation, following the child's lead, and providing positive reinforcement for every verbal attempt were found to be implemented by mothers of toddlers with the highest TNP. In contrast, toddlers with the least TNP were found to have lesser imitation attempts and usage of only confrontation naming for verbal response elicitation by the mothers.

Number and type of vowels in terms of tongue height (low (open), open mid, close-mid, and high (close) vowels) in Malayalam speaking toddlers with TD and toddlers with RCP±L

Analysis of vowels in terms of tongue height revealed that the low (open) vowel /a/ was the most frequently produced vowel and the open mid vowel /ə / was produced least frequently by the toddlers with TD and RCP±L. In toddlers with RCP±L, nasalization of vowels was observed. In comparison, toddlers with RCP±L had more frequent productions of low (open) vowel /a/ and significantly lesser productions of close-mid and high (close) vowels than toddlers with TD.

Low (open) vowel /a/ one of the first speech sounds to be mastered [29], was the most frequently produced vowel by the toddlers with TD and RCP±L in the study. This was also reported by Eshghi, Vallino, Baylis, et al, [14] in their study on nine toddlers with RCP±L at 12, 14, and 18 months of age. Only toddler TD 01 had similar production of low (open) vowels and close-mid vowels. This can be attributed to the vocabulary used by the child during the interaction session. In all the toddlers except for RCP±L 03, open mid vowel /ə /, produced in the middle of the oral

cavity was found to be produced with the lowest frequency as compared to the close-mid vowels and high (close) vowels. These findings can be attributed to the late acquisition of open mid vowels into the phonetic inventory compared to the vowels /a/, /i/, and /u/ [30]. The lesser frequency of open mid vowel evidenced in toddlers with RCP±L in the current study is similar to the findings in 11- 18-year-old Tamil speaking toddlers with URCLP as reported by Sreedhanya, Hariharan & Nagarajan [9]. Malayalam speaking adults in the age range of 30-55 years have been reported by Sreedevi & Irfana [21] to produce low vowel /a/ most frequently and open mid vowel /ə/ least frequently, these findings also indicate the acquisition of adult vowel inventory by the Malayalam speaking toddlers with TD and RCP±L in the current study.

The cleft speech characteristic of nasalization of vowels was observed in Malayalam speaking toddlers with RCP±L (RCP±L 01, RCP±L 04, and RCP±L 05), as reported among the Tamil speaking toddlers with URCLP [9]. These findings can be attributed to the restraint on the velopharyngeal function caused by increased tongue height [20,31] affecting the speech sound productions or the phonetic context of their productions [32]. RCP±L 05 aged 2.7 years with the primary palatal surgery carried out at twelve months of age, had nasalized production of all vowels. The highest frequency (19.32%) of nasalized production was for the low (open) vowel /a/, followed by high (close) vowels (9.96%), close-mid vowels (8.03%), and open mid vowel (0.24%), indicative of velopharyngeal dysfunction. RCP±L 04 had nasalization of low (open) vowel /a/ and nasalization of close-mid vowels. Nasalization of low (open) vowel /a/ was frequently observed in RCP±L 04 in varied contexts such as in isolation (21%), in CV combination with plosives (14.11%), in words with fricatives (17.6%) and words with semivowels (16.47%). Thus, it can be stated that nasalization of low (open) vowel /a/ exhibited by RCP±L 04 in varied contexts of

syllable environment (predominantly pressure consonants) and the vowel position in a syllable or word indicated the possibility of contextual effect [33]. RCP±L 01 had nasalization of close-mid vowels. This finding can be attributed to the high tongue position adopted for the production of the close mid vowels leading to the creation of more acoustic impedance than low (open) and open mid vowels [31].

A comparison of the frequency of vowel productions between toddlers with TD and RCP±L revealed that only low (open) vowel /a/ was produced with higher frequency by toddlers with RCP±L than toddlers with TD. The productions of vowels with increased tongue height such as close-mid and high (close) vowels were found to be significantly lesser in toddlers with RCP±L, than in toddlers with TD. These findings were similar to the findings by Sreedhanya, Hariharan & Nagarajan [9] that 11- 18-month-old Tamil speaking toddlers with URCLP produced open vowels significantly more frequently than closed vowels.

Hence, it can be summarized that the vowel inventory of Malayalam speaking toddlers with RCP±L has less frequent occurrences of closed vowels, that are produced with increased tongue height than open vowels produced with lesser tongue height. Qualitatively, toddlers with RCP±L exhibited CSCs.

Vowel productions in terms of tongue advancement

Number and type of vowels in terms of tongue advancement (central, front, and back vowels) in Malayalam speaking toddlers with TD and toddlers with RCP±L

Analysis of vowels in terms of tongue advancement revealed that central vowels /a/ and /ə/ were most frequently produced, whereas back vowels /u/ and /o/ were produced least frequently by toddlers with TD and RCP±L. In toddlers with RCP±L, nasalization of vowels was observed. In comparison, toddlers with RCP±L had more frequent production of central vowels and

significantly lesser productions of front and back vowels in comparison to toddlers with TD.

Among the most frequently produced central vowels, the central low vowel /a/ was produced with the highest frequency by the toddlers with TD and RCP±L. This can be attributed to the earlier age of acquisition of the central vowel /a/ as stated by Wellman, Case, Mengert, et al, [29], and also better accuracy of production of vowel /a/ as compared to other vowels as stated by Stoel-Gammon, Carol & Herrington [34]. Central open mid vowel /ə/ had lesser frequency than central vowels, as they are acquired soon after or along with the acquisition of central vowel /a/ as stated by Selby & Robby [30]. Back vowels are produced least frequently by all the toddlers (except for RCP±L 03). Similar findings were reported in a longitudinal study carried out on Tamil speaking toddlers with TD and RCLP during their vocalization and verbalization phase by Hariharan [12] and also in 11- 18 month Tamil speaking toddlers with TD and URCLP by Sreedhanya, Hariharan & Nagarajan [9]. Similar findings were reported by Sreedevi & Irfana [21] among Malayalam speaking adults in the age range of 30-55 years. Hence, it can be stated that the 30- 36-month-old Malayalam speaking toddlers with TD and RCP±L in the current study exhibited adult vowel inventory patterns.

Nasalization of vowels was observed in Malayalam speaking toddlers with RCP±L (RCP±L 01, RCP±L 04, and RCP±L 05), as reported among Tamil speaking toddlers with URCLP and RCLP [9,12]. Nasalization of vowels can be attributed to the effect on the velopharyngeal function caused by tongue advancement [35], increased tongue height [20,31] affecting the speech sound productions, or the phonetic context of their productions [32]. Toddlers with RCP±L (RCP±L 04 and RCP±L 05) exhibited the highest nasalization for the central vowels, in contrast to findings of greater nasalization for front vowels by Bressmann, Radovanovic, Harper, et al, [35]. These differences can be attributed to the participant characteristics. It

was found that RCP±L 05 had exhibited nasalization of all vowels, even in words with and without pressure consonants indicating velopharyngeal dysfunction. RCP±L 04 was found to exhibit nasalization of central vowels primarily in words with nasals or pressure consonants, thereby indicating the contextual effect [33]. RCP±L 04 had nasalized back vowel productions (close mid /o/ and high vowel /u/), which can be attributed to the increased tongue height during their production [2], higher points of pharyngeal wall contacts, greater velar excursion and tighter seal of the velopharyngeal port [33]. This finding is in contrast to the findings by Lewis, Watterson & Quint [19] and Bressmann, Radovanovic, Harper et al, [35]. This could be because RCP±L 04 was found to produce /ũ/ inconsistently only during the production of the onomatopoeic word /ku/ (cluck of a hen), indicating nasalization of vowel /u/ in the syllable environment of a pressure consonant. RCP±L 01 had nasalization of back vowel /õ/.

Comparison between the vowel productions of toddlers with TD and toddlers with RCP±L revealed that the frequency of production of central vowels was higher in toddlers with RCP±L compared to toddlers with TD. Similar findings were reported during the vocalization and verbalization phase of toddlers with RCLP by Hariharan [12]. These findings are contrary to the greater occurrence of back vowels reported in 11-18-month-old Tamil speaking toddlers with URCLP by Sreedhanya, Hariharan & Nagarajan [9]. This difference can be attributed to the fact that the participants of the current study had an early palatal repair (Mean -10.6 months) and the recording was carried out between 30-36 months of age. Thus, early palatal repair could have facilitated the acquisition of vowel inventory by Malayalam speaking toddlers with RCP±L similar to that of toddlers with TD. Significantly higher productions of front and back vowels were observed in toddlers with TD as compared to toddlers with RCP±L in the current study. Higher frequency of front

vowel productions and significantly higher frequency of back vowel productions were reported in Tamil speaking toddlers with TD as compared to Tamil speaking toddlers with RCLP by Hariharan [12] during their vocalization and verbalization phases.

Hence, it can be summarized that the vowel inventory of Malayalam speaking toddlers with RCP±L has more frequent occurrences of central vowels produced in the middle of the oral cavity than the front and back vowels produced in the extremities of the oral cavity. Qualitatively, toddlers with RCP±L exhibited CSCs.

Another crucial finding observed in all the toddlers with TD and RCP±L was that the tense vowels (/a:/, /i:/, /e:/, /o:/, /u:/) were produced with lesser frequency than lax vowels (/a/, /i/, /u/, /e/, /o/). This can be attributed to the fact that tense vowels are usually produced with extreme tongue positions and greater durations than lax vowels, and this might be the reason for the lesser frequency of production of tense vowels by all the toddlers in the study. Malayalam speaking adults have been reported by Sreedevi & Irfana [21] to have a greater frequency of lax vowels than tense vowel productions. Also, lax vowels appear only in closed syllables [28] and the majority of the utterances produced by all the toddlers in the study were closed syllables.

CONCLUSION

Investigation and comparison of the vowel productions in Malayalam speaking toddlers (aged 30-36 months of age) with RCP±L and toddlers with TD revealed individual variations between the participants in terms of the total number of vowel productions and the frequency of each type of vowel. Analysis of vowels in terms of tongue height revealed that the low (open) vowel /a/ was the most frequently produced vowel whereas the open mid vowel /ə / was produced least frequently by the toddlers with TD and RCP±L. Analysis of vowels in terms of tongue advancement revealed that central vowels /a/ and /ə/ (predominantly low vowel /a/) were most frequently produced, whereas

back vowels /u/ and /o/ were produced least frequently by toddlers with TD and RCP±L. Toddlers with RCP±L were found to have significantly lesser productions of close-mid, high (close), front, and back vowels in comparison to toddlers with TD. In toddlers with RCP±L (RCP±L 01, RCP±L04 and RCP±L05), nasalization of vowels was also evidenced.

Declaration by Authors

Ethical Approval: Ethical clearance was obtained from the All-India Institute of Speech and Hearing (AIISH) WOF-170/2018-19 dated 21-12-2020 and also from the National Institute of Speech and Hearing (NISH) letter No: IEC201903 dated 17-07-2020 for the conduct of the study. Informed consent was obtained from each participant adhering to the guidelines stipulated by AIISH and NISH.

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