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ORIGINAL STUDY

Perceptual and Acoustical Assessment of Voice in Children With Cleft Lip and Palate

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Abstract

Background: **The speech of individuals with cleft lip and palate is primarily characterized by nasality of oral speech because of cleft and or velopharyngeal dysfunction.**

Objectives: **The aim of the present study is to investigate the acoustical assessment and perceptual rating measurements in cleft lip and palate children.**

Methods: **The study participants included 30 children with cleft lip and palate in the age range of 4–12 years. Prior parental consent was obtained for the inclusion of their children in the study. Speech analysis of all the l the participants were recorded. Prerecorded speech samples of the CLP groups were mixed randomized and played, using headphone in a quiet room. The speech-language pathologist (SLP) rated the nasality of the participant. Samples for perceptual evaluation are 15 phonation samples of/ă/,/ɪ/and/ŭ/vowels vowel, 15 conversation samples and 30 subjects (3 oral sentences each so total 90 sentences).**

Results: **For the Phonation sample, SLP must evaluate the presence of hypernasality by Wilcoksons nasality scale. Acoustic analysis was done using PRAAT software. The spectral and temporal parameters were measured. The Kappa coefficient was 0.88 for inter-rater reliability for nasality rating scale, 0.82 for speech intelligibility,1.02 for speech understandability,1.00 for speech acceptability, which suggests substantial agreement between the raters for four different rating scales.**

Conclusion: **Hence both acoustical and perceptual evaluation play an important role in children with CLP.**

Keywords: Cleft lip, Cleft palate, Nasality, PRAAT software

1. Introduction

Cleft lip and palate (CLP) are a congenital structural anomaly caused by atypical embryological development. Craniofacial anomalies are a result of interruption in embryologic growth between the 4th and 10th week of embryonic development [1]. Individuals with CLP are commonly seen with speech problems like weak or omitted consonants, short utterances, altered rate and speech segment duration, compensatory or obligatory articulation productions, and voice problems associated with hypernasality, hypo nasality, denasality, cul de sac resonance, nasal air emission as a resonance problem [2].

The speech of individuals with cleft lip and palate is primarily characterized by nasality of oral speech because of cleft and or velopharyngeal dysfunction.

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The inability to close the velopharyngeal port during speech in individuals with CLP results in the escape of sound energy directly through the nasal cavity and thus, the nasality is increased in these individuals. Compensatory and obligatory errors are very common among cleft lip and palate individuals with reduced voice qualityultimately resulting in altered speech intelligibility [3,4].

Nasal Resonance is a commonly seen condition in CLP individuals and is considered as important parameter of resonance aspects related to speech production and perception. The varying shape of the vocal tract results in a change of resonance characteristics of speech. Individuals with cleft lip or palate (CLP) have disorders in speech dominantly exhibiting hypernasality and exhibits articulation, resonance, and voice disorders leading to unintelligible speech [3].

Various studies were carried out on perceptual evaluation by advocating different types of stimuli which include phonation of vowels, repetition of high-pressure consonants, words, sentences (oral, nasal, and oronasal) for children, and passages (Zoo and Rainbow). The zoo passage [4,5] was one among the traditionally used stimuli to assess, as it consists of various oral consonants (stops, fricatives, and glides) with 83 syllable lengths to obtain valid and stable measures.

Assessment through listening is also the standard method for speech assessment in patients with cleft lip and palate [6,7]. The method for assessment at the cleft palate clinics in Sweden has been developed over the years through discussions and collaborations between the team of speech and language pathologists. A test material, named as the Swedish test of articulation and nasality was released in 2005 with a comprehensive manual which is now used at cleft palate clinics for evaluation of speech at all age groups. The assessment of resonance and articulation is performed in one session which is usually audio recorded to ensure the possibility of making a detailed transcription of it and allowing for listening later for clinical and research purposes. The test material includes single words, sentences, and elicitation of continuous speech of an individual. This has been recommended to ensure a comprehensive evaluation [9,10].

Various factors such as the type of stimuli, phonetic context, voice quality, the pattern of articulation, the listener's previous experiences, and expectations influenced the perceptual evaluation [3,11–16]. The perception of hypernasality varies as a function of other aspects of speech. It is more severe on high vowels than on low vowels [17,18] and varies according to phonetic context [19]. The perceptual judgments by observers are not presented with convincing reliability. This could be due to variable internal standards acquired by different individuals, i.e., all observer experiences are thought to be stored in the memory and are believed to form the internal standards [20–22].

The speech of individuals with repaired cleft lip and palate and velopharyngeal dysfunction can be evaluated primarily using perceptual evaluation [3,7,8]. The perceptual rating scales usually vary from four to eleven points [23,24] and the most widely used is the five-point rating scale (normal nasality, mild, moderate, severe, and very severe hypernasality or nasal emission). The studies based on the "trained ears or perceptual assessment" to obtain a reliable and valid assessment of hypernasality in individuals with Cleft lip and palate are very limited and most of the studies have been done on evaluation of cleft lip and palate speech in a different context, but the studies using different stimulus like phonation, sentences, and conversation on evaluation are scanty. Hence, the present study was conducted on the perceptual and acoustical evaluation of cleft lip and palate children's speech across stimuli.

2. Aim

The aim of the study was to investigate the acoustical assessment and perceptual rating measurements of voice in individuals with cleft lip and palate.

3. Method

3.1. Participants

The study was conducted on 30 children with cleft lip and palate in the age range of 4–12 years. Before the study parental consent was obtained. The criteria for the study were as follows -

3.2. Inclusion criteria

1. Children with repaired cleft lip and palate were included in the study.
2. All children underwent late surgery.
3. Children with operated cleft lip and cleft palate with evidence of nasality in their speech with and without articulatory errors.
4. Children with a language age of 3 years i.e., those who could repeat sentences and conversation for assessment.

The exclusionary criteria for the study were as follows.

3.3. Exclusion criteria

1. Children with evidence of normal resonance, hypo nasality, and mixed resonance were excluded from the study.
2. Children with hearing loss of more than moderate degrees were excluded from the study.
3. Children with active upper respiratory tract infections at the time of recording are excluded.
4. Children with behavioral and sensory issues are excluded.

3.4. Speech sample recording procedure -

Speech samples of all the participants were recorded in a quiet environment by the investigator using a Sony digital recorder kept 15 cm away from the mouth of the speakers. Speech samples included phonation of vowels, repetition of pre-structured sentences (oral) in the Kannada language, and conversation samples were recorded.

Three speech-language pathologists (SLP) with a minimum experience of 3 years in the perceptual assessment of cleft speech did the perceptual evaluation of nasality.

Prerecorded speech samples of the individuals of the CLP groups were mixed, randomized and played, using headphone conditions in a quiet room. The SLPs rated the nasality of the participant.

Samples given for perceptual evaluation were 15 phonation samples of/a/,/i/and/u/vowel, 15 conversation samples and 30 subjects (3 oral sentences each so total 90 sentences).

For the Phonation sample, SLP evaluated the presence of hypernasality by Wilcoksons nasality scale. The SLPs analyzed the samples for the presence of normal resonance/hypernasality/hypo nasality/mixed nasality/cul-de-sac resonance. Only the samples identified as having hypernasality were rated by using a Wilcox son's rating scale.

Standard rating scales like Wilcox son's nasality rating scale, a 7-point rating scale for speech intelligibility, speech understandability, and speech acceptability scales were used for the perceptual assessment by the investigator. Speech-Language Pathologist listened to the samples of individuals with cleft lip and palate which were pre-recorded and rated the sample in terms of its nasality, intelligibility, understandability, and acceptability.

3.5. For objective assessment

For acoustic measurement of cleft lip and palate, each participant was seated comfortably on the chair, and samples were recorded with a constant microphone which was 15 cm away from the mouth of the participants.

Consent from the mother of each child was taken concerning the participation of the children in the study. The noisy and distractive environment was avoided.

The study was carried out in the following phases.

1. Recording of speech samples of 30 children with cleft lip and palate.
2. Acoustic analysis of the samples using PRAAT software.

3.6. Phase 1: recording of the speech sample

PRAAT software was used for the recording of the samples. Children were seated comfortably in front of the system and recorded the pre-structured oral sentences. Followed by phonation of vowels and involved the children in a general conversation for 2–3 min.

3.7. Phase 2: acoustic analysis of voice

After the data collection, each recorded sample was saved in the hard disk of a system (with 64-bit resolution and Windows 7 operating system), the recorded sample of each speech sample at a time was line fed into the computer and stored on the computer. The waveform of the digitalized acoustic signal of the speech sample was produced by children were displayed on the computer screen and subjected to acoustical analysis by using PRAAT software, version 6.0. Each sample was displayed on the computer monitor and then by visual inspection. The investigator moved the cursor from the beginning to the end of the signal i.e., end of the waveform and listened to the same by playing the highlighted waveform. Once it is confirmed auditorily later each sample was highlighted, then stored it as a file. Later Acoustic analysis of each speech sample like sentences, conversation, and phonation was performed by extracting the below-mentioned parameters like acoustic parameter from the speech samples of children with cleft lip and palate.

The speech samples of all 30 children were analyzed and edited and the digitalized data were

used for analysis. The waveform and spectrogram of each samples were displayed using PRAAT software. Each sample was selected by moving the cursor from starting to the end of the signal. The highlighted portion was displayed on the screen by clicking the 'self-option. Then the 'pulse' menu was clicked and from the drop-down menu, 'voice report' was selected. The software displayed the values of the following acoustic parameters (i) average fundamental frequency (F0), (ii) Minimum fundamental frequency, (iii) Maximum fundamental frequency, (iv) Standard deviation (SD) of the fundamental frequency, (v) Jitter (Local), (vi) Jitter (Absolute), (vii) Jitter (Rap), (viii) Jitter (PPQ 5), (ix) Jitter (DDP), (x) Shimmer (Local), (xi) Shimmer (dB), (xii) Shimmer (APQ 3), (xiii) Shimmer (APQ 5), (xiv) Shimmer (APQ 11), (xv) Shimmer (DDA), (xvi) Noise to Harmonic ratio, (xvii) Harmonic to Noise ratio, (xviii) Number of voice breaks, and (xix) Degree of voice breaks. Along with these parameters, Formant frequency 1, Formant Frequency 2, and Formant Frequency 3 were included. The values were noted and the sample was analyzed using the same procedure.

To obtain the value of Formant 1, each sample was highlighted by moving the cursor from the beginning to the end of the sample by visual and auditory confirmation of the sample. From the menu, the "formant" option was clicked and from the drop-down menu "Get first formant" was selected. The value displayed by the software was noted. Similarly, the "formant" option was selected from the menu, and from the drop-down menu "Get the second formant" was clicked to obtain the value of Formant 2. The value of Formant 2 was noted. Using the same procedure, values of Formant 1, Formant 2, and Formant 3 were noted for all the samples of the CLP.

3.8. Statistical analysis

For studying inter-and intra– rater reliability of the three judges, the kappa coefficient was calculated.

Mean and standard deviation (SD) values of all parameters were calculated for each stimulus like a sentence, phonation, and conversation for the cleft lip and palate group. ANOVA test was carried out to check the significance among different stimuli.

SPSS Version 20 software was used for statistical analysis.

4. Results

Table 1 depicts the mean and standard deviation values of voice acoustical parameters for the cleft lip and palate group. Mean and standard deviation

Table 1. Depicted the mean and standard deviation values for the acoustic parameters

		Mean	Std. Deviation
Average F0	Sentences	269.1034	54.20039
	Conversation	263.3040	41.37992
	Phonation	263.5200	42.50486
Minimum F0	Sentences	200.0260	66.24333
	Conversation	174.9000	52.82538
	Phonation	188.9175	84.46748
Maximum F0	Sentences	366.5155	87.36072
	Conversation	430.1710	74.72304
	Phonation	340.0669	75.86918
SD for F0	Sentences	34.1603	20.23201
	Conversation	43.0630	21.43004
	Phonation	27.6832	32.37078
Jitter (L)	Sentences	2.1120	.78391
	Conversation	2.2570	.92719
	Phonation	1.6131	1.53260
Jitter (ABS)	Sentences	78.3049	34.88578
	Conversation	86.5960	25.65527
	Phonation	76.2900	63.73766
Jitter (RAP)	Sentences	1.0713	.44295
	Conversation	1.0660	.47808
	Phonation	.9759	.86526
Jitter (PPQ)	Sentences	1.1211	.48345
	Conversation	1.0330	.44525
	Phonation	.9294	.86507
Jitter (DDP)	Sentences	3.2124	1.30181
	Conversation	3.2030	1.43968
	Phonation	2.7998	2.64740
Shimmer (L)	Sentences	12.4920	5.71561
	Conversation	10.6430	3.89952
	Phonation	13.0756	8.13699
Shimmer (dB)	Sentences	1.1671	.43336
	Conversation	1.0350	.28203
	Phonation	1.1625	.64760
Shimmer (APQ3)	Sentences	5.8478	3.04921
	Conversation	4.5860	1.12255
	Phonation	6.5230	4.07426
Shimmer (APQ5)	Sentences	8.3228	4.48316
	Conversation	6.3740	2.58717
	Phonation	9.0356	5.91726
Shimmer (APQ11)	Sentences	13.3590	7.75130
	Conversation	10.8680	2.70304
	Phonation	13.0025	9.81397
Shimmer DDA	Sentences	17.5406	9.16450
	Conversation	15.0060	6.07512
	Phonation	20.1044	12.32825
NHR	Sentences	.2157	.11884
	Conversation	.2270	.10361
	Phonation	.1827	.18151
HNR	Sentences	10.3917	4.15178
	Conversation	9.3700	2.58504
	Phonation	12.6214	7.63831
F1	Sentences	716.3624	121.47051
	Conversation	943.3000	112.36777
	Phonation	670.1463	178.60815
F2	Sentences	1841.5520	163.88073
	Conversation	2092.7300	43.54951
	Phonation	1750.9656	407.65628
F3	Sentences	3004.4609	192.11325
	Conversation	3255.3400	173.85716
	Phonation	2986.1563	307.52136

(*continued on next page*)

Table 1. (continued)

		Mean	Std. Deviation
Intensity	Sentences	74.6152	8.32100
	Conversation	60.4000	14.59338
	Phonation	65.6819	12.37138
No. of Voice Break	Sentences	3.4828	1.66958
	Conversation	39.8000	15.09820
	Phonation	1.8125	3.16689
Degree of Voice Break	Sentences	19.9693	11.73665
	Conversation	64.2800	11.09204
	Phonation	6.7112	12.27529

values of average F0, Minimum F0, Maximum F0, SD of F0, Jitter values, Shimmer values, and Noise related values are not statistically significant and by inspection, there is no such variation in terms of its values for sentences, conversation, and phonation. Mean and SD values for F1, F2, and F3 values are higher in conversation than compared to sentences and phonation. The number of voice breaks and degree of voice breaks are higher in conversation than compared to sentences.

ANOVA indicated that there is no such significant difference was present in all the acoustical parameters in the cleft lip and palate group. There are no significant differences observed for average F0, Minimum F0, Maximum F0, SD of F0, Jitter values, Shimmer values, and Noise related parameters, and Formant Frequency parameters. Thus, to conclude voice parameters do not vary significantly in cleft lip and palate children across different samples like phonation, sentences, and conversation.

5. Discussion

5.1. Perceptual analysis of nasality for sentences

All the samples were rated as hypernasality in the cleft lip and palate group which indicated that more than 50% of the children had mild hypernasality, whereas moderate hypernasality was present in the remaining 40% of the samples and 20% of samples have severe nasality.

5.2. Perceptual analysis of speech understandability

All the samples were rated as mild and moderate rating i.e., speech is occasionally hard to understand, and speech is often hard to understand ratings from all three raters.

5.3. Perceptual analysis of speech acceptability

All the samples were rated as mild and moderate rating i.e., speech deviates from normal to mild degree i.e., 1 rating point and speech are deviating from normal to moderate degree i.e., 2 rating points for all the samples.

5.4. Perceptual analysis of speech intelligibility

All the samples were rated as '2', '3', '4' ratings i.e., 2 − Listener's attention needed.

3 − Occasional repetition of words needed, 4 − Repetition and rephrasing necessary.

5.5. Reliability of perceptual ratings − inter-rater reliability

The Kappa coefficient was 0.88 for inter-rater reliability for nasality rating scale, 0.82 for speech intelligibility, 1.02 for speech understandability, 1.00 for speech acceptability, which suggests substantial agreement between the raters for four different rating scales.

The good inter-rater reliability obtained in the present study could have been due to the good quality of recordings with good listening conditions during analysis and the experience of the raters in the perceptual assessment of hypernasality.

Research also indicates that a scale with fewer scale points increases the inter-and intra– rater reliability. The rating scale used in the present study was a 5-point scale with a rating solely of hyper nasality. Simultaneous rating of various parameters such as hypernasality, nasal emission, misarticulation, and intelligibility by the listener reduces the reliability and efficiency of the readings. Other domains like speech intelligibility, speech understandability, and speech acceptability also have fewer points of rating.

5.6. Acoustical analysis of voice in cleft lip and palate children

Spectral analysis was used to explore the acoustic properties of speech in individuals with cleft lip and palate by Watterson et al. [24] In the present study acoustic analysis of children with cleft lip and palate was done by using PRAAT software. The review of the literature suggested that only the spectrographic method is used widely no such studies are reported on acoustical analysis along with perceptual analysis.

6. Conclusion

To conclude in children with cleft lip and palate both acoustical and perceptual evaluation plays an important role while assessing the speech domain by using different kinds of speech stimuli. Although there is no such variation across speech stimuli for

different stimuli like phonation, sentences, and conversation. While collecting samples from the individual with cleft lip and palate different kinds of speech sampling must be included. The results are however limited for the Kannada language and further studies need to be conducted across different languages on larger study samples for generalization of the findings.

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Conflict of interest

Authors declare that there was no conflict of interest.

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