CHAPTER III

METHOD

3.1 Participants

The study included analyses of both acoustic and perceptual speech characteristics in children with cleft palate (CLP) before and after primary palate surgery and comparing the same with typically developing children (TDC). The participants for the study included nonsyndromic children with unoperated complete cleft palate /cleft of soft palate who visited unit for structural oro-facial anomalies (U-SOFA), at the All India Institute of Speech and Hearing, and plastic surgery unit, Vikram hospital, Mysuru for consultation. Apart from these children, information about the unoperated children was also collected from the database of U-SOFA and plastic surgery unit, Vikram hospital, Mysuru. About 40 parents of unoperated children were contacted through a phone call. Out of 40 children 15 children were not operated and their parents were asked for a follow-up consultation. Out of 15 children only five children came for the follow-up consultation and remaining were not reported. Another nine children were collected from U-SOFA who came for consultation from the craniofacial team. Based on the inclusion and exclusion criteria, the present study considered 14 (7 Males and 7 Females) Kannada speaking children with congenital unoperated cleft palate (Clinical group) in the age range of five to ten years (Mean age = 7 Years) and they were considered as Group I. Further, group I was divided into two subgroups. They are group 1 (pre-operative condition) and group 1 (post-operative condition). The same children of group I (pre-operative condition) who underwent surgical intervention were considered as group I-(post-operative condition). Post-surgical recording for the group I- (post-operative condition) was done after one month when the children were brought for a follow-up visit. Age and gender matched 50 typically developing children (TDC) were considered as Group II (Control group). In each age range, (5 to 10 years) a total of 10 children (5 males & 5 females) were considered. Participants demographic details of both clinical/ control groups are depicted in Table 1.
Table 1

Demographic details of both clinical/ control groups

<table>
<thead>
<tr>
<th>Participants</th>
<th>Age (Years)</th>
<th>Gender</th>
<th>Socio- Economic status</th>
<th>Provisional Diagnosis</th>
<th>Type of surgery</th>
<th>Category of surgery</th>
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<tbody>
<tr>
<td></td>
<td>Age/Age</td>
<td>Mean</td>
<td>Male</td>
<td>Female</td>
<td>Lower</td>
<td>Middle</td>
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<tr>
<td>Group I</td>
<td>Range</td>
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<tr>
<td>(Pre-postoperative</td>
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<tr>
<td>Group II</td>
<td>5 to 10</td>
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<td>7</td>
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<td>(TDC)</td>
<td>9</td>
<td>M</td>
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Note: [M=Male, F= Female, CCC-Congenital complete cleft of palate, CCSP- Congenital cleft of soft palate, TFP- Two-flap palatoplasty, FDOZ-Furlow’s Double Opposing Z plasty, TDC=typically developing children, NA- not applicable]

3.1.1. Participation selection criteria.

The following criteria were considered for the selection of the participants in the present study.

Inclusion criteria for Group I- Pre-operative condition

- Children in the age range of five to ten years
- Children with Kannada\(^1\) as their native language
- Children diagnosed and evaluated by the craniofacial team at unit for structural oro-facial anomalies (U-SOFA), All India Institute of Speech and Hearing, Mysore for unoperated complete cleft palate /cleft of soft palate were considered. The craniofacial team includes a Plastic surgeon, Speech-Language Pathologist, and orthodontist.

\(^1\) Kannada is one of the main Dravidian languages of India, spoken mainly in the state of Karnataka. Kannada has several dialects, they are known as the Dharwar or North Karnataka dialect, the Karwar dialect, the Mysore dialect and so on. The basic Kannada vowel system consists of five long and five short vowel phonemes. Kannada has a native Dravidian inventory of consonants, with a superimposed system of aspirated consonants and supplementary sibilants borrowed from indo-Aryan, and with /\(\theta\)/ and /\(\phi\)/ borrowed from Urdu and reinforced by English loans. In Kannada, consonants do not occur in final positions (Schiffman, 1979).
• Assessment checklist for the speech-language domain (Swapna, Jayaram, Prema & Geetha, 2013) was used for screening on receptive and expressive language levels. Children with receptive and expressive levels above four years were considered.
• No history of persisting middle ear problems for all the children.
• All the children were matched for socioeconomic status by using re-adapted version of National Institute of Mental Health (NIMH) Socioeconomic Status Scale (Venkatesan, 2009).

Inclusion criteria for Group I-Post-operative condition

• Same children of Group I-Pre operative condition who underwent primary palatal surgery were considered for Group I-Post-operative condition.
• Children who underwent successful surgery were considered for operated children group and, the success of the surgery was certified by plastic/maxillofacial surgeon.

Inclusion criteria for Group II (TDC)

• Typically developing children were screened for sensory and motor development using WHO -Ten disability checklists (Singhi, Kumar, Malhi, & Kumar, 2007) and those who passed the checklist were considered.
• Children in the age range of five to ten years
• Children with Kannada as their native language
• Children with hearing sensitivity in normal limits with no middle ear pathologies.

Exclusion criteria for Group I- Pre-operative condition

• Children with syndromic cleft conditions were excluded from the study.
• Children with wide cleft and submucous cleft were not considered.
• Children who underwent only early lip repair were not considered for the study.
- Children with below average intelligence/cognitive impairments were excluded based on IQ assessment reported by Clinical Psychologist.

Exclusion criteria for Group I-Post-operative condition

- Children with incomplete closure of cleft / presence of fistula were not considered for the study.
- At the time of recording children who had a cold /cough /upper respiratory tract infection were not included.
- Children with a frequent history of otitis media/ adenoidectomy were not included for the study.

Exclusion criteria for group II (TDC)

- At the time of recording children who had a cold/cough /upper respiratory tract infection were not considered.
- Children with a frequent history of otitis media/ adenoidectomy were not included.
- Children with enlarged tonsils were not considered.

3.2 Ethical consideration

The study was conducted with the clearance from AIISH Biobehavioural ethical committee and with the written consent from parents/caregivers of children with CLP. Parents/caregivers were provided information about the aim, objective and approximate duration of testing. (Appendix-1)

The study aimed to analyze the acoustic and perceptual parameters. The procedure, materials adopted for the same are discussed separately.

3.3 Preparation of Materials for Acoustic Analyses

Materials: The aim of acoustic analyses was to study the different temporal and spectral parameters from the speech of children with CLP in the pre-operative and post-operative condition and to compare the same with TDC. Hence, the data was collected from children with CLP in both conditions (pre and post-operative condition) and from TDC. Lists of words and sentences were prepared for the purpose
of acoustic and perceptual evaluation. For acoustic analyses, bisyllabic Kannada words loaded with pressure consonants and nasal continuants were served as stimuli for the present study. The details of the procedure for selection of wordlist for acoustic analyses are as follows,

**Selection of wordlist for acoustic analyses:** Test material for acoustic analyses included pressure consonants (/p/, /b/, /t/, /d/, /ʈ/, /ɖ/, /k/, and /ɡ/), affricates (/ʧ/, /ʤ/) and fricatives (/s/) and nasal continuants. Using these consonants, a list of 40 bisyllabic Kannada words were selected from the Kannada text books of first and second grade and Kannada dictionary. The selected bisyllabic words had pressure consonants in the initial position followed by short vowel /a/ and those in the medial positions preceded by low mid open vowel /a:/. (Eg: For target pressure (oral) consonant /k/- Ꙙ /kas/- Initial position; Ꙙ /a:ke/- Medial position. For target nasal continuants /m/- Ꙙ /mane/- Initial position; Ꙙ /a:me/- Medial position). This wordlist was given to three experienced Speech-Language Pathologists (mean age of 42.3 years) who were proficient in Kannada language (speaking and reading) for rating the wordlist. They were asked to judge the selected words according to the content specifically on the target pressure consonants by using two point rating scale. Content validity of the selected wordlist was rated using a two point rating scale (1= No target consonants, 2= Presence of target pressure consonants). The rated target words received from the judges were compiled. Out of 40 bisyllabic Kannada words the judges selected only 22 words. Totally eleven oral words in the initial position and eleven oral words in the medial position formed the oral test stimuli. Two nasal continuants in the initial position and two in the medial position formed the nasal test stimuli. Hence, totally the stimuli consisted of twenty-two (22) oral words and four (4) nasal words for acoustic analyses (Appendix-2).

### 3.4 Preparation of Materials for Perceptual Analyses

The present study was also aimed to study the perceptual analyses by profiling the different attributes of perceptual speech characteristics in children with CLP across conditions. Hence the data was collected only from children with CLP in the pre and post-operative conditions.
For perceptual analyses, bisyllabic Kannada words loaded with pressure consonants, Kannada sentences loaded with pressure consonants and conversational speech served as stimuli. The same bisyllabic Kannada words selected for the acoustic analyses were considered for perceptual evaluation (except for nasal continuants). The details of the procedure for construction of sentences are as follows,

**Construction of sentence list for perceptual analyses:** For the purpose of perceptual analyses, three meaningful Kannada sentences loaded with target pressure consonants (/p/, /b/, /ʈ/, /ɖ/, /ʈʃ/, /ɖʒ/, and /ɡ/) were constructed for each target consonants with the help of native Kannada speaker based on the speech sampling guidelines provided by Henningsson et al., (2008). For the construction of sentences, words were selected from Kannada language based on Kannada phonetic reader (Upadhyaya, 1972). From the selected words, totally 33 meaningful oral Kannada sentences were constructed (3 sentences for each pressure consonants). While constructing the sentences, it was made sure that the sentences were simple, short, easy to remember and meaningful. Each sentence consisted of three to four words. These sentences were subjected to content validity by the same three experienced Speech-Language Pathologists (SLPs) who served as judges for judging the content validity of words for acoustic analyses. The judges were asked to judge the constructed sentences according to the content specifically on the target pressure consonants by using four point rating scale. Content validity of the constructed sentence list was rated using a Likert type ordinal four point rating scale (1= No target consonants in the sentences, 2=loaded with 25% of target consonants in the sentence, 3=loaded with 50% of target consonants in the sentence, 4=loaded with 75% of target consonants in the sentence).

The rated target sentences received from the judges were compiled. Sentences that were rated as 3 and 4 in four point rating scale were considered as stimuli. Out of 33 sentences totally 22 oral sentences were selected based on the rating. Four standardized nasal sentences in the Kannada language were considered from a study by Jayakumar and Pushpavathi (2005). Sentence stimuli for perceptual evaluation consisted of 22 oral sentences and 4 nasal sentences (Appendix-2).

The finalized word and sentence list were audio recorded using Cool Edit Pro version 2.00 with the help of a Kannada native female speaker with an inter-stimuli
interval of 5 seconds in a quiet room. Recorded word and sentences list were given to 5 native Kannada speakers for perceptual analyses to confirm that all the sentences and words are articulated correctly. This recorded sample served as a model for recording speech sample from children.

*Conversational speech:* To elicit conversation, a set of questions related to the participant’s family, school/friends and hobbies were listed. The conversation sample was audio-video recorded for a minimum duration of five to ten minutes (approximately to elicit 100 to 150 words) depending on the cooperation from the participant. The audio-video recordings of the conversational speech were considered for the perceptual assessment of speech understandability and acceptability. This was collected only from children with CLP in pre and post-operative conditions.

### 3.5 Procedure

Children diagnosed as having congenital unoperated cleft by the craniofacial team were considered for the study. The acoustic and perceptual analyses were carried out for children with CLP before and after surgery.

*Recording:* Children were seated comfortably in a quiet room and the data was collected individually. Children were asked to listen to the speech model provided through the headphone (HD 457) and repeat the bisyllabic words three times clearly and repeat the sentences once, clearly in their comfortable pitch and loudness. Repeated words were 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. Sentences and conversational speech were audio-video recorded using Sony digital video camera recorder (DCR-SR88E) which served as stimuli for perceptual analyses. The same procedure was followed after 1 month of the surgery to obtain the post-operative recordings. For typically developing children only bisyllabic words were audio recorded for acoustical analyses. Recorded words from the control group were only considered for acoustic analyses. The bisyllable words recorded from the clinical group (both pre and post-operative condition) were used for both acoustic and perceptual analyses. All the recordings were carried out by the investigator.
Data Analyses: The collected speech samples were subjected to two types of analyses, which included acoustic and perceptual analyses. The acoustic analyses were carried out for children with CLP across pre and post-operative conditions and typically developing children. But perceptual evaluation was done only for children with CLP across conditions.

3.6 Acoustic Analyses

Before the acoustic analyses, the recorded speech sample of target words from children with CLP was subjected to auditory perception and spectrographic inspection.

Auditory perception and spectrographic inspection: The speech sample obtained by children with CLP in both pre and post conditions were subjected to auditory perception and spectrographic inspection by three experienced Speech-Language Pathologists (Mean age = 37.3 Years) who had clinical and research experience in analyzing the speech of CLP. Among three judges, the investigator also served as one of the judge for auditory perception and spectrographic inspection. Other two judges were trained for auditory perception and spectrographic inspection by the investigator. During training, they were provided information related to speech characteristics in CLP and few spectrograms related to the temporal and spectral parameters considered for the study. After the training, they were asked to carry out the auditory perception and spectrographic inspection task.

Training for auditory perception and spectrographic inspection: Three judges performed auditory perception and spectrographic inspection for selecting the words
for acoustic analyses. Among three judges investigator also served as one of the judge. The other two judges were trained by the investigator for auditory perception and spectrographic inspection. It was done by using speech sample of five pre-recorded words of typically developing children and speech sample of children with CLP. Speech sample of children with CLP which was characterized by hypernasality, nasal air emission, and articulation errors were selected for auditory perception and spectrographic inspection. Training for auditory perception and spectrographic inspection was carried out in five sessions each lasted for one hour. During, first two training sessions, the judges were provided information about temporal and spectral parameters measurement included in the study and features to be observed for the target consonants using TDC sample. In the speech sample of children with CLP, the judges were asked to listen to the uttered target words carefully and inspect spectrographically (using Praat software version 5.3.35). They were asked to consider all the parameters for the study from the waveform using wide band bar type spectrogram as a reference. During training session, the judges were monitored for the analyses of a speech sample of CLP and feedback was provided about the parameters to be inspected by the investigator. The speech samples of children with CLP, which were included in the training session, were not considered for the main study.

**Instruction for the judges:** After completion of the training for auditory perception and spectrographic inspection judges were provided with audio recorded speech sample of target words from children with CLP. They were asked to listen carefully and spectrographically inspect all the three uttered target words using Praat software version 5.3.35 from a waveform with the wideband bar type spectrogram as a reference. During the auditory perception and spectrographic inspection, they were also asked to rate all the uttered words on a three-point rating scale. In which, ‘0’ indicated as ‘unintelligible’ and ‘1’ indicated as ‘intelligible approximating to the target word by 25%, ‘2’ indicated as ‘intelligible approximating to the target word by 50% and ‘3’ indicated as intelligible approximating to the target word by 75%. The rated target words from the judges were compiled. Words that were rated as ‘intelligible approximating to the target word by 50-75% were selected for analyses. The selected target word samples of children with CLP were retained and other uttered words were removed using Cool Edit Pro (version 2.00). The retained words
from the samples of children with CLP were considered for further detailed acoustical analyses by the investigator. The same procedure was followed for all the samples.

The audio-recorded speech samples (words) from all the groups were analyzed using Praat software version 5.3.35 (Boersma & Weenink, 2012) for calculating temporal and spectral parameters. Each word was showed 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. Wideband bar type spectrogram showed in monochrome (black and white) on the linear scale. The speech samples of TDC were analyzed directly using Praat software (version 5.3.35).

3.6.1 Acoustic analyses of temporal and spectral parameters

The temporal and spectral parameters considered for the study are depicted in the table below.

Table 2

Temporal and spectral parameters considered for acoustical analyses in children with CLP across conditions and TDC.

<table>
<thead>
<tr>
<th>Temporal parameters</th>
<th>Spectral parameters</th>
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<tbody>
<tr>
<td>Word Duration (WD)</td>
<td>First formant frequency (F₁)</td>
</tr>
<tr>
<td>Vowel Duration (VD)</td>
<td>Second formant frequency (F₂)</td>
</tr>
<tr>
<td>Syllable Duration (SyD)</td>
<td>Third formant frequency (F₃)</td>
</tr>
<tr>
<td>Total Duration (TD)</td>
<td>First bandwidth (B₁)</td>
</tr>
<tr>
<td>Closure Duration (CD)</td>
<td>Second bandwidth (B₂)</td>
</tr>
<tr>
<td>Voice Onset Time (VOT)</td>
<td>Third bandwidth (B₃)</td>
</tr>
<tr>
<td>Burst Duration (BD)</td>
<td>F₂ Onset frequency</td>
</tr>
<tr>
<td>Voicing Duration (VoD)</td>
<td></td>
</tr>
<tr>
<td>Affrication Duration (AD)</td>
<td></td>
</tr>
<tr>
<td>Fricative/Frication Duration (FD)</td>
<td></td>
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</tbody>
</table>

Temporal Parameters: The temporal parameters considered for acoustical analyses were measured from the waveform with wideband bar type spectrogram as a reference. The words were analyzed from pre and post-operative conditions from
children with CLP and TDC. The measurements of these parameters were done as follows,

**Word Duration (WD):** Word duration for words containing stops, affricates, fricative and nasal continuants were analyzed. It is the time difference between the onset of the target word and offset of the target word. On the wideband bar type spectrogram, word duration was measured by placing the cursor at the onset and offset of the word. Figure 2 illustrates the measurement of the word duration.

![Waveform and wideband bar type spectrogram showing word duration of /gatəld/](image)

*Figure 2. Waveform and wideband bar type spectrogram showing word duration of /gatəld/.*

**Vowel Duration (VD):** Vowel duration was analyzed for preceding vowel of the target consonants in word medial position (VCV). It is the time difference between the onset and offset of the vowel. On the wideband bar type spectrogram, vowel duration was measured as the time difference between the onset of the first glottal pulse represented by the first voice bar and the offset of the glottal pulse represented by the last voice bar. Figure 3 illustrates the measurements of vowel duration.
Figure 3. Waveform and wideband bar type spectrogram showing measurement of vowel duration /a:/ in the word /a: ke/ (Duration of the vowel /a:/ between two vertical cursors).

**Syllable Duration (SyD):** Syllable duration was analyzed in word medial position (VCV) for all the target consonants. It is the time difference between the onset and offset of the target syllable. On the wideband bar type spectrogram, syllable duration was measured by placing the cursor at the onset and offset of the syllable in the word medial position. Figure 4 illustrates the measurement of the syllable duration.

Figure 4. Waveform and wideband bar type spectrogram showing SyD of /ða/ in the word /a: ða/.

**Total duration (TD):** Total duration is measured as the time difference between the onset of the closure of stop consonants to the onset of the following vowel in word-medial position. On the wideband bar type spectrogram, total duration was measured as the time difference between the offset of voicing for the preceding vowel and the onset of the voicing for the following vowel indicated by voice bars on the baseline. Figures 5 and 6 illustrate the measurements of TD in unvoiced and voiced plosives, respectively.
Figure 5. Waveform and wideband bar type spectrogram showing Total duration (TD) of /k/ in the word /a: ke/.

Figure 6. Waveform and wideband bar type spectrogram showing Total duration (TD) of /g/ in the word /a: ge/.

Closure Duration (CD): Closure duration is measured as the time difference between the onset of the closure and the articulatory release in the production of a word-medial stop. On the wideband bar type spectrogram, closure duration was measured as the time difference between the offset of voicing for the preceding vowel and onset of the burst indicated by irregular vertical striations. Figures 7 and 8 illustrate the measurements of closure duration in unvoiced and voiced plosives, respectively.
Figure 7. Waveform and wideband bar type spectrogram showing closure duration (CD) of /k/ in the word /a: ke/.

Figure 8. Waveform and wideband bar type spectrogram showing closure duration (CD) of /g/ in the word /a: ge/.

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 the burst (OB) depicted as irregular vertical striations and the onset of the voicing (OV) depicted as voice bars on the baseline. Figures 9 and 10 illustrate the measurement of VOT in voiced and unvoiced plosives respectively.
Figure 9. Waveform and wideband bar type spectrogram showing VOT for the voiced /g/ in the syllable /gal/.

Figure 10. Waveform and wideband bar type spectrogram showing VOT for the unvoiced /k/ in the syllable /kal/.

Burst Duration (BD): Burst duration was measured as the time difference between the onset and offset of the articulatory release in a word-initial stop consonant. On the wideband bar type spectrogram, the cursor was placed at the point of onset of the burst (OB) depicted as irregular vertical striations and offset of burst and time striations was noted. Figure 11 illustrates the measurement of the burst duration.
**Voicing Duration (VoD):** It is the time difference between the onset of voicing to the offset of voicing in a word-initial stop consonants/affricates. Voicing is represented by the voice bars or vertical regular striations on the baseline of the wideband bar type spectrogram. Figure 12 illustrates the measurement of voicing duration.

**Fricative/Frication duration (FD):** It is the time difference between the onset and offset of the frication in a word-initial position. On the wideband bar type spectrogram, fricative duration was measured by placing the cursor at the onset and offset of the frication. Figure 13 illustrates the measurement of the frication/fricative duration.
Figure 13. Waveform and wideband bar type spectrogram showing FD of /s/ in the syllable /sa/.

Affricate duration (AD): It is the time difference between the onset and offset of the affrication in a word-initial position. On the wideband bar type spectrogram, affrication duration was measured by placing the cursor at the onset and offset of the affrication. Figure 14, 15 illustrates the measurement of the unvoiced and voiced affrication duration.

Figure 14. Waveform and wideband bar type spectrogram showing affrication duration of /ʧ/ in the word /ʧaʈa/.

Figure 15. Waveform and wideband bar type spectrogram showing affrication duration of /dʒ/ in the word /dʒaɖa/.
Spectral Parameters: The extraction of each spectral parameter was considered for the study are described below,

Formant frequencies and Bandwidth: These are the responses of the vocal tract and are depicted as dark bands on the wideband bar type spectrogram. They are numbered starting from the baseline of the wideband bar type spectrogram. Wideband bar type spectrogram formant tracking was used to measure $F_1$, $F_2$, and $F_3$. The cursor was kept at the center point of the steady state of the vowel and value was noted for formats. At the same point bandwidth $B_1$, $B_2$, $B_3$ values were extracted and noted using Praat software version 5.3.35.

Figure 16. Wideband bar type spectrogram showing $F_1$, $F_2$ and $F_3$ of vowel /a/ in the syllable /ga/.

$F_2$ Onset frequency: It is the frequency of the onset of $F_2$ of the following vowel /a/ in the CV context. The onset of the $F_2$ transition was identified at the point of $F_2$ onset following the release of a consonant.

Figure 17. Wideband bar type spectrogram showing $F_2$ Onset frequency (arrow) of /g/ in the syllable /ga/.
Acoustic analyses of data in CLP

Speech sample of children with CLP in the pre and post-operative conditions were subjected to auditory perception and spectrographic inspection by experienced SLP. This verification task was executed to confirm that children with CLP have uttered the target words correctly. Based on the verification task the samples were selected for acoustical analyses. Acoustical analyses of temporal and spectral parameters were measured from the waveform with wideband bar type spectrogram as a reference as mentioned. However, few limitations were observed during the analyses of the speech sample of CLP in the present study. The samples were selected at least 50% to 75% intelligible approximating to the target words. Some of the speech samples of children with CLP in unoperated and operated conditions were characterized by compensatory articulation, hypernasality, severe nasal air emission and weak oral pressure consonants. Word samples which exhibited many articulatory errors and other features were not considered for the analyses as the wideband bar type spectrograms showed nasal murmur due to which the temporal and spectral parameters of speech characteristics were not clear for analyses. However, other CLP speech characteristics such as hypernasality and weak oral pressure consonants were considered for further analyses. These two errors were considered because even though there was dampening/loss of the acoustic energy, information related to temporal and spectral parameters of speech characteristics were retained to some extent related to the target pressure consonants.

3.7 Perceptual Analyses of Speech Characteristics in children with CLP

Apart from acoustical analyses, the speech samples of children with CLP were also subjected to perceptual analyses. The speech characteristics in children with CLP were analyzed using a perceptual scale developed by Henningsson et al., (2008). There are a number of standardized perceptual scales/protocols that are developed to analyze the speech of person with cleft palate (American Cleft Palate-Craniofacial Association, 1993; John, Sell, Sweeney, Harding-Bell & Williams, 2006; Lohmander & Olsson, 2004; Rudnick & Sie, 2008; Sell, Harding, & Grunwell, 1999). Among the standardized assessment protocol universal parameters for reporting speech outcome in the cleft palate proposed by Henningsson et al., (2008) is widely used across cleft clinic for perceptual analyses. Universal reporting parameters include articulatory
error analyses, hypernasality, hyponasality, nasal turbulence, nasal air emission and consonants errors, grimaces, speech intelligibility, and acceptability. However, very few studies have reported speech outcome in CLP across pre-post-operative conditions. Hence, the universal parameter for reporting speech outcome in cleft palate was adopted to perceptually analyze the speech across pre and post-operative conditions in the present study.

*Training for perceptual evaluation:* Same judges who performed auditory and spectrographic inspection for selecting the words for acoustic analyses were considered for auditory perceptual judgment task. The other two judges were trained by the investigator for perceptual judgment task by using five pre-recorded words, sentences and conversational speech samples of children with CLP. Only those speech samples of children with cleft palate characterized by hypernasality, nasal air emission, and articulation errors were selected for training. Listening training session was carried out in five sessions and each session lasted for one hour. Training sessions for the judges included familiarity of different terminologies and definitions used in the perceptual scale which was explained by the investigator.

The speech samples (words, sentences) were randomized and presented to the judges for perceptual assessment. Among three judges, the investigator served as one of the judges for perceptual assessment. During training, the judges were provided with a glossary of terminologies and descriptions of the parameters to be analyzed. Judges were asked to rate the speech sample of children with CLP using the universal reporting parameters. The mean perceptual rating scores of all the judges for each sample were calculated for each trial and the judges were provided feedback to correct their error. Speech samples of CLP included for the training session were not considered for the main study. For perceptual analyses speech characteristics such as articulatory characteristics, resonatory characteristics and speech understandability and acceptability were considered. The analyses of speech characteristics are described below.

*Articulation:* A list of 11 Kannada words recorded for acoustic analyses (except nasal continuants) and audio-video recorded 26 sentences were considered for perceptual assessment of articulation in children with CLP across conditions. Sentences were audio-video recorded by the investigator simultaneously on a repetition task as
children with CLP were asked to repeat the sentences when the model was provided. The speech samples across conditions were randomized while providing to the judges for perceptual analyses. The recorded video consisted of the demographic details about the children and sentence repetition sample. Speech samples (sentence) of children with CLP were retained and other information was edited using AVS Video remaker version 4.3.1.161 for perceptual analyses. Judges were asked to listen to the speech samples (both bisyllabic words and sentences) of children with CLP carefully and mark present (+) and absent (-) of the articulatory errors using universal reporting parameters by Henningsson et al., (2008) (Appendix-3).

Further, cleft type characteristics were classified under six categories, the first category is atypical backing of oral sounds to post uvular place. This category includes both pharyngeal and glottal production of a target oral pressure consonant. A pharyngeal production includes pharyngeal fricatives, pharyngeal stops, and/or pharyngeal affricates. Glottal productions include glottal stops and glottal fricatives. In the present study pharyngeal fricatives/affricates, pharyngeal stops and glottal stops were considered. Second, the abnormal backing of oral sounds but the place remains oral. In this group sounds that are backed and produced as mid-dorsum palatal productions, velar productions, or uvular productions are considered. In the present study, only mid-dorsum palatal stops were considered. Third, nasal fricative is a nasal production that replaces high-pressure consonants and may be produced as voiceless nasals. The nasal fricative may be produced with or without turbulence (Trost, 1981). Fourth, Nasal sounds are substituted for the oral sounds in this group. An error frequently involves stop consonants where the target stop consonants are substituted with a nasal continuant as a passive activity (Hutters & Brondsted, 1987; Harding & Grunwell, 1998). Fifth category includes, Nasalized voiced pressure consonants. In this group most of the voiced consonants are nasalized (Hutters & Brondsted, 1987; Harding & Grunwell, 1998). Perceptually, the target stop consonant maintains its features but loses some or most of its oral quality. Sixth, is a weak oral pressure consonant and in this category error it is an overall loss of energy in the production of high-pressure consonants.
Resonance: Resonance characteristics such as hypernasality, hyponasality and nasal air emission of children with CLP across conditions were assessed using the bisyllabic words, sentences which consisted of both oral and nasal sentences.

Hypernasality: It is defined as excessive nasal resonance heard on vowel and sometimes on voiced consonants (McWilliams et al., 1990). The recorded 11 Kannada oral target consonants loaded words and 22 oral target consonants loaded sentences from children with CLP across conditions served as speech sample for judgment of hypernasality. The same judges were asked to listen to the speech sample carefully and judge the hypernasality using four-point rating scale (0-3) (0= within normal limits, 1= Mild, 2= Moderate, 3=Severe) by Henningsson et al., (2008).

Hyponasality: Hyponasality is defined as decreased or insufficient nasal resonance heard on nasal continuants and vowel (McWilliams et al., 1990). Four nasally loaded standardized sentences in Kannada language (adopted from Jayakumar and Pushpavathi (2005) were considered for perceptual judgment of hyponasality. The repeated nasal sentences of children with CLP were randomized and played through headphones to the judges for the assessment of hyponasality. Judges were asked to judge using binary rating scale (0= within normal limits, 1= present) provided by Henningsson et al., (2008).

Nasal air emission: Nasal air emission is defined as the audible escape of air through the nasal passage that accompanies, or is coproduced with, high-pressure consonants (McWilliams et al., 1990). The audio recorded 11 Kannada oral target consonants loaded words and video recorded 22 oral target consonants loaded sentences from children with CLP across conditions served as speech sample for assessing nasal air emission. The speech samples were presented in a randomized order across speakers and conditions. It was judged on binary choice such as present (+), and absent (-) as proposed by Henningsson et al., (2008).

Speech understandability and acceptability: Speech understandability is explained as the degree to which the individual message can be understood by the listener (Henningsson et al., 2008). These parameters were assessed using the conversational speech where, each participant was asked to speak about their family, school, and hobbies for at least ten minutes. The recorded speech samples were rated using four-
point rating scale (0-3). Speech acceptability is explained as the degree to which speech calls attention to itself apart from the content of spoken message. SLP’s were asked to rate using four point rating scale as per Henningsson et al., (2008). The details are provided in table 3.

Table 3

Rating scale used for the assessment of speech understandability and acceptability


<table>
<thead>
<tr>
<th>Severity rating</th>
<th>Speech Understandability</th>
<th>Speech Acceptability</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-Within normal limits</td>
<td>Speech is always easy to understand</td>
<td>Speech is Normal</td>
</tr>
<tr>
<td>1-Mild</td>
<td>Speech is occasionally hard to understand</td>
<td>Speech deviates from normal to a mild degree</td>
</tr>
<tr>
<td>2-Moderate</td>
<td>Speech is often hard to understand,</td>
<td>Speech deviates from normal to a moderate degree</td>
</tr>
<tr>
<td>3-Severe</td>
<td>Speech is hard to understand most or all the time</td>
<td>Speech deviates from normal to a severe degree</td>
</tr>
</tbody>
</table>

_Intra and Inter-judge reliability_

The same three trained experienced Speech-Language Pathologists who served as judges for auditory and spectrographic inspection and perceptual assessment served as judges for intrajudge reliability task for acoustic and perceptual analyses. Among the three SLPs, the investigator also served as one of the judges for assessing intra-reliability judgment. Ten percent of the speech samples of typically developing children were selected randomly for Intra and inter-judge reliability of acoustic analyses. Sixty percent of the clinical group (pre-post) samples were selected randomly for both acoustic and perceptual evaluation for Intra and inter-judge reliability. Interjudge reliability was done after six weeks of the completion of the analyses. The data obtained from acoustic and perceptual analyses were considered for statistical analyses using the Statistical Package for the Social Sciences (SPPS 20.0.) software package.

3.8 **Statistical Analyses**

The acoustically analyzed data of sixty-four participants were compiled across two groups [50 typically developing children (TDC) and 14 children with cleft palate (CLP)]. Typically developing children were further divided into two groups based on
their gender. Children with cleft palate were further divided into two conditions (Condition I – pre-operative, Condition II-post operative) for analyses of temporal and spectral parameters. Recorded speech samples from children with CLP were perceptually analyzed for speech parameters pre and post operatively. The quantitative and qualitative data obtained were subjected to tests of normality, and depending upon results of normality parametric and non-parametric statistical analyses were employed using Statistical Package for Social Sciences (SPSS) version 21.

The main objective of the study was to investigate the temporal and spectral parameters in children with CLP in the pre and post-operative conditions and to compare with TDC. The analyzed quantitative data obtained from temporal and spectral parameters were subjected to the following statistical analyses,

- Descriptive statistics (Mean, Standard deviation, and Median) for temporal and spectral parameters were obtained for all the quantitative data.

- To check the normality, obtained quantitative data was subjected to normality by using the Shapiro-Wilk’s test. Before performing the normality test, for identification outliers, box plots were drawn for all the variables. Outliers were found in both upper and a lower end in temporal and spectral parameters such as word duration, syllable duration, VD, F₁, F₂, F₃ onset frequency, voice onset time, total duration. Identified outliers were removed from the sample in each group. After removing outliers the normality was checked with Shapiro-Wilk’s test. If there was any improvement found in the consistency of the data in Shapiro-Wilk’s test then same was retained. If the removal of outlier failed to improve the consistency of the data in Shapiro-Wilk’s test than the outliers were not removed for both TDC and CLP. Based on the Shapiro-Wilk’s test results parametric statistics and non-parametric statistics were administered.

- Shapiro-Wilks test of normality was done for quantitative data obtained from ten temporal and seven spectral parameters to find whether the data followed a normal distribution or not in TDC and children with CLP across the gender. The results of Shapiro-Wilk's test on temporal and spectral parameters for TDC across the gender showed normal distribution (p>0.05), thus repeated
measure of ANOVA (with gender as between factor) was carried out to find significant difference across gender, type (voiced/unvoiced), interaction effect between gender and type (voiced/unvoiced) in temporal and spectral parameters in TDC.

- Among TDC, gender was the only independent variable for fricatives and nasal continuants. Hence, MANOVA was performed to find out the significant difference across the gender.

- Some data in temporal and spectral parameters of TDC and CLP did not follow a normal distribution (p<0.05) in Shapiro-Wilks test. Hence, these parameters were subjected to a non-parametric test using Mann-Whitney U test and Wilcoxon’s signed rank test. Mann-Whitney U test was used to find out the significant difference across the gender in TDC and CLP group. Wilcoxon’s signed rank test was used to find the significant difference across the type (voiced/unvoiced) in TDC and CLP group.

Intra and Inter-Judge Reliability in TDC

The Intra and inter-judge agreement were analyzed for acoustic analyses in TDC. The intrajudge reliability measures indicated that, acceptable to good internal consistency among the judges for acoustic analyses measurements. Cronbach’s alpha scores for intrajudge reliability ranged from 0.61 to 0.97 across the temporal and spectral parameters. Inter-judge reliability measures indicated, good to excellent internal consistency across the measurements. Cronbach’s alpha scores for interjudge reliability ranged from 0.87 to 0.97 across the temporal and spectral parameters.

Intra and Inter-Judge Reliability in children with CLP

The Intra and inter-judge agreement for acoustic analyses in children with CLP were analyzed. The intrajudge reliability measures indicated, acceptable to good internal consistency among the judges for acoustic analyses measurements. Cronbach’s alpha scores for intrajudge reliability ranged from 0.63 to 0.82 across the temporal and spectral parameters. Inter-judge reliability measures indicated that, acceptable to good internal consistency across the measurements. Cronbach’s alpha scores for interjudge reliability ranged from 0.71 to 0.86 across the temporal and spectral parameters.
The Intra and inter-judge reliability agreement for perceptual analyses in children with CLP were analyzed for articulation, resonance, and speech intelligibility. The results of Intra and inter-judge reliability are as follows. The Cronbach’s alpha values for articulatory errors in stop consonants in children with CLP across condition and stimuli were obtained. The intrajudge reliability measures indicated that, acceptable to good internal consistency among the judges for perceptual analyses. Cronbach’s alpha scores for intrajudge reliability ranged from 0.67 to 0.85. Inter-judge reliability measures indicated acceptable to good internal consistency across the measurements. Cronbach’s alpha scores for interjudge reliability ranged from 0.62 to 0.79.

The Intra and inter-judge reliability for articulatory errors in fricatives and affricates were analyzed across conditions and stimuli. Results of the inter and intrajudge reliability revealed Cronbach's alpha scores which ranged from 0.63 to 0.87 and interjudge reliability ranged from 0.61 to 0.79 which indicated acceptable to good internal consistency. The Intra and inter-judge reliability for articulatory errors due to nasalization were analyzed across condition and stimuli. Results of inter and intrajudge reliability indicated Cronbach’s alpha scores ranged from 0.64 to 0.82 and for inter-judge reliability the range from 0.61 to 0.79 which indicated acceptable to good internal consistency. The Intra and inter-judge reliability for hypernasality and nasal air emission were analyzed across conditions and stimuli. Results of inter and intrajudge reliability revealed that Cronbach’s alpha scores ranging from 0.71 to 0.85 and inter-judge reliability ranged from 0.62 to 0.80 which indicated acceptable to good internal consistency. The Intra and inter-judge reliability for speech understandability and acceptability were analyzed across conditions. Results of inter and intrajudge reliability revealed Cronbach’s alpha scores ranging from 0.74 to 0.84 and inter-judge reliability ranged from 0.71 to 0.78 which indicated acceptable to good internal consistency.