CHAPTER II

REVIEW OF LITERATURE

Speech is a difficult form of human behavior, which is based on the organic structure of the central nervous system and orofacial structure. It also depends upon various developmental, psychosocial, and environmental factors. If any one of these structures fails in their function, it can directly impact the oral communication. One of the most frequently occurring birth defects/ deformities is cleft lip and palate (CLP). Children with CLP are often associated with feeding problems, nutritional concerns, and middle ear problems/ reduced hearing sensitivity, communication problems, dental problems and psychosocial impairments. The presence of speech language disorders in persons with CLP have been reported by Grunwell et al., (1993); McWilliams et al., (1990); Nagarajan, Savitha, and Subramaniyan (2009).

Incidence and prevalence of the orofacial clefts mainly cleft lip and palate (CLP), and cleft palate alone (CP) are main public health problems occurring 1 in every 500 to 1000 births worldwide (Cooper et al., 2000; Murry, 2002). World Health Organization (2002) reported that every 2 minutes a baby is born with a cleft somewhere in the world. In India, the frequency of occurrence of children born with CLP was around 28,600 which mean 78 new born in a day, or 3 babies with clefts are born every hour (Mossey & Little, 2009).

A study by Raju (2000) reported the occurrence of cleft lip/palate is about one in 781 live births. He also reported that 36,000 babies with cleft lip/palate are born in India every year. A survey carried out by Tata Institute of Social Sciences reported that 25% of the children with CLP have undergone a surgical correction and they are from an urban area of higher social economic status. The majority of individuals are reported in the rural areas, and they do not undergo any of the treatment due to as they are unaware of the conditions and services available related to the treatment, hence most of them do not get early intervention. However, surgical corrections are focused on normalizing the appearance of the individuals with CLP. Even after effective surgical corrections, speech problems are frequently seen in individuals with CLP. As per National Sample Survey Organization (2002) report, cleft lip/palate is 17 per 1000
persons in all sectors that causes speech disability, in which, 15 per 1000 are from rural and 21 per 1000 are from urban sectors.

Reddy et al., (2010) studied the incidence of CLP in three districts in the state of Andhra Pradesh in India. They found that birth rate of clefts was 1.02 per 1000 live births. Banerji and Dhakar (2013) reported the birth prevalence of clefts approximately between 27,000 and 33,000 per year. In India, occurrence of cleft lip is estimated as 9.1 per 10,000 depending upon a number of epidemiological factors such as geography location, ethnicity, and socio-demographic parameter. Another retrospective study was conducted by Nambiar, Singhal, Menon and Unnikrishnan (2014) to determine the Clinico-epidemiological profile of CLP in the district of Mangalore in Karnataka state in India. Five years birth data was collected from the birth records of the hospitals. The results revealed that cleft occurrence in Mangalore was found to be 2.42/1000 live births per year. Cleft lip along with cleft palate was found to be the highest (64.6 %), followed by the isolated cleft lip (28.5%), and followed by isolated cleft palate (5.1%) and last being the isolated cleft lip with cleft alveolus (1.9%).

Management of children with CLP requires an interdisciplinary approach, which requires a longer time and the outcome of the treatment, is affected by multiple factors. Children with CLP require a dedicated team to provide a quality cleft care. They work in an interdisciplinary and coordinated team. The team involves a Plastic/Maxillofacial surgeon, SLPs, Orthodontist, parents/family members. In a team approach, professionals specialized in cleft care, assess and provide coordinated treatment to children with CLP and care for their families, and engage in inter-professional communication within the team.

The main difficulty about following a team-based approach for the treatment of individuals with CLP in developing countries is that the professionals who represent the cleft care team are either unavailable or limited in number. Also, the dental and orthodontic services for children with CL/P require long-term follow-up. These services are not readily accessible or affordable to children with CL/P in developing countries. Speech-language therapy services are often not available or extremely limited in developing countries (D’Antonio & Nagarajan, 2003; Sell, 2007; Gopalakrishna & Agarwal, 2010). To overcome some of the issues, International
teams sponsored by charity organizations provide free surgical interventions in countries where the facilities for repair of the cleft are not available, and also train the professionals for cleft care.

Among the available management options, first and primary focus becomes the surgical correction of the cleft in children with CLP. There have been a number of surgical techniques used for cleft palate closure. However, different surgeons use different techniques for cleft palate repair. There are many variations of each of these techniques as reported by Agarwal (2009). He reported few widely practicing surgical techniques. To name a few techniques, Von Langenbeck’s bipedicle flap, Veau-Wardill-Kilner Palatoplasty, Bardach Two-flap Palatoplasty, Furlow Double Opposing Z-Plasty, Two-stage Palatoplasty, One-stage cleft lip and palate repair, Alveolar Extension Palatoplasty a Vomer flap, Hole in one repair, and Raw area free palatoplasty. Among all the available surgical procedures, children with CLP in the present study were operated using two-flap palatoplasty and Furlow Double Opposing Z-Plasty. Two-flap palatoplasty was described by Von Langenbeck and it is also called as Von Langenbeck’s bipedicle flap. The procedure was carried out by using flaps from mucous membrane and periosteum for the repair. The front portion of the flap up to the alveolar margin makes it as two flaps. Formerly only the cleft boundaries were dissected, and a side opening was prepared, than the flap was raised from the hard palate, the palatal muscles were separated and at end the stitches were made. This method is still performed in surgical management of isolated cleft palate repair.

Furlow Double Opposing Z-Plasty was named after Furlow (1986) who used a double reverse method for the oral and nasal surfaces of the soft palate. The hard palate area is stitched by creating an opening in the side of the cleft edges, by raising the mucous membrane and periosteum from the center and making use of the high arch, the cleft is sutured in two layers without making a side opening. It was reported that on the interchanges of double reverse method provides an effective lengthening of the soft palate observed.

Speech is assessed as one of the main outcome method of CLP management and yet its assessment method is challenging for Speech-Language Pathologists (SLPs). In spite of the challenges, there are no universal agreements for speech
evaluation methods for CLP. Speech and language characteristics associated in children with CLP have been derived from perceptually based information. Data obtained from anatomic, radiographic and electromyographic studies have been documented and the physiologic influence of velopharyngeal valving on speech have been cited/reported widely in the literature (Ha et al., 2007; Raphael, 1975; Vorperian & Kent, 2007; Vorperian et al., 2009; Yamashita et al., 1992; Yashmitha & Michi, 1991).

The surgical outcome of speech has been documented by perceptual and acoustic methods. Perceptual evaluation is considered as gold standard for the assessment of speech in persons with CLP. There are number of perceptual assessment scales reported in the literature (Grunwell et al., 1993; Henningson et al., 2008; Howard & Heselwood, 2002; Kuehn & Moller, 2000; Lohmander & Olsson, 2004; McWilliams et al., 1990; Sell, 2005). Another outcome measure is the acoustic analyses using spectrogram, which helps to examine the speech characteristics resulting from synchronous and in order interactions of phonation, articulation, and resonation, as these happen in real time speech productions. Spectrographic analyses have not been used regularly in relation to velopharyngeal incompetence, although their potential has been suggested by a number of authors (Hyde, 1968; Lindblom, Lubker, & Pauli, 1977; Horii, 1980; Kunkel et al., 1998). The studies using acoustical method have used either spectral or temporal aspects. Millard (1968) had opined that the spectrograph could offer objective information, which would be of help in deciding the type of treatment, evaluating the results of service and diagnosing the speech disorders of those who have VPD.

2.1 Acoustic analyses of speech in children with CLP

2.1.1 Temporal characteristics in children with CLP

The sounds of speech are the product of actions of the complex acoustic system called the vocal tract. The acoustic analyses provide an extraordinarily potential tool for assessing speech system function. One of the most powerful acoustic analyses techniques is Sound Spectrography. Speech characteristics of vowels and consonants have been studied and reported extensively in the literature using spectrograms in the typically developing children and in some of the communication
disorders. However, the studies related to the acoustical analyses of the speech of children with CLP are very scanty. The following section briefly summarizes the acoustic correlates of speech in children with CLP.

Among the acoustic correlates of speech, speech segment duration is the indicator of the abilities to coordinate speech gestures, durational properties of the speech signal. It reflects the interactions of the mechanism’s components to meet segmental and supra-segmental requirements of meaningful speech (Forner, 1983). Philips and Kent (1984) have explained the influence of nasalization. Nasalized sounds tend to have a dominant low-frequency region of sound energy, a reduction of overall sound energy is reported to be around 5-10 dB (Sonninen & Lehtonen, 1982), and fairly uniform distribution of energy over the mid-frequency region of the spectrum. This is because of the anatomic nature of nasal tract over the oral tract.

Lass (1984) reported that nasalized vowels in wideband spectrograms are similar to their non-nasalized counterparts. Nevertheless, possess the nasal characteristics as a distortion superimposed on the vowel spectrum (Fant, 1970). The acoustic correlates of nasalization of vowel includes, (1) presence of the low-frequency nasal formant below F₁ of the non-nasalized sounds, (2) a weaken and small frequency increase of F₁, (3) a decrease of the overall energy in comparison to non-nasalized vowels, (4) frequently, a reduction of F₂ amplitude and increase formant bandwidths. The overall effect of these acoustic changes is to make nasalized vowels less intense, more concentrated with low-frequency energy, and uniform spread of energy in the middle frequencies. Some authors believe that nasalization diminishes the acoustic differentiations of vowels (Curtis, 1968; Sonninen & Lehtonen, 1982).

A study by D’Antonio (1982) indicated that the duration of phonetic section in CVC utterances was longer for individuals with cleft palate than normal individuals. Forner (1983) acoustically analyzed the segment duration uttered by 15 children with RCLP in five to six years of age with different grades of hypernasality and compared with 15 typically developing children. The stimulus formed was 5 nonsense consonant syllables using /p/, /t/, /k/, /tʃ/, /s/. The closure duration, voice onset time (VOT), vowel duration, frication and affrication duration, and total duration were extracted using spectrograms. The closure duration of stops and affricates were found to be
longer. She reported that children with CLP had longer voice onset time, syllable duration and total sentence duration when compared to that of normal children. The results showed that the duration of acoustic-phonetic sections in CVC utterance was longer in individuals with cleft palate compared to normal children. In general, children with cleft palate who showed low speech intelligibility scores were reported to have longer acoustic phonetic segments than children with cleft palate with high intelligibility scores. The individuals with low speech intelligibility scores showed a greater variability of segment duration and more frequent instances of aberrant timing patterns. She further speculated that prolonged segmental duration may be a purposeful feature used to compensate for damped sound energy. She also opined that abnormal use of the respiratory mechanism may result in a stress-like emphasis on all the utterances or it may be a combination of factors related to compensation and abnormal use of the mechanism to reach the feature target phoneme. Wang, et al., (1993) quantitatively evaluated the acoustic characteristics of glottal stop and normal production of /ka/ in normal children and children with cleft palate spectrographically. They found that, 20 msec in the normal production of /ka/ with an average time of 44.6msec. In the cleft palate group of /ka/ average time was found to be 20.8 msec.

In the Indian context, Vasanthi (2001) investigated a few temporal and spectral characteristics of speech in two adults with RCLP and compared with typical adults. Twelve words, which consisted of target pressure consonants, were recorded and spectrographically analyzed for vowel duration, voice onset time, total duration and F₁, F₂, Terminal frequency (TF1) and Terminal frequency (TF2) using Speech Science Lab. She reported that, terminal frequency F2 (TF2) was lesser than normal adults. Similarly, the frication and affrication duration was reported to be shorter in speech sample of an adult with CLP. She observed that in an adult with CLP, the preceding vowel duration was increased to keep constant syllable duration. She also made few common observations in both the speakers with cleft palate. She also reported that VOT was longer for unvoiced stops and for burst duration for plosives were not clear, and lower F₂ was observed for both the speakers with CLP. She reported that this may be due to velopharyngeal insufficiency observed in the adults with repaired CLP which caused longer VOT and lower F2 in her study.
Casal et al., (2002) measured spectral features in the speech of 22 children with repaired CLP and matched with TDC in the age range of 4 to 12 years. Spanish vowels /a/, /i/, /u/, /e/, /o/, stops and nasal continuants /p/, /t/, /k/ and /m/ served as stimuli. They analyzed F1, F2, burst duration, and VOT using spectrograms. Results of their study showed a significant difference between the TDC and the cleft children in the F1 of /e/ and in the frequency of /t/ burst. Significant difference in the F1 for /o/, F2 of /a/ and /o/ across groups were also reported. Their results point out a small but significant effect of the cleft lip or its repair on lip rounding for vowel /o/ and /u/. In addition, the difference in tongue placement was also attributed to be accountable for the differences seen with /a/ and /e/. They concluded that spectrographic differences in their subjects did not contribute to meaningful differences in speech sound development. They also reported that individual care should be provided for normalization of speech development.

Among the temporal parameters, VOT has been studied frequently in children with CLP. Gamiz, Fernandez-Valades, Calle, Amador and Mendoza (2006) evaluated the acoustic parameters that change the VOT in operated children with CLP. they reported of an increased VOT, which was attributed to irregular teeth occlusion and normal function of the soft palate. An increase in duration was also reported to have been affected by cleft lip and delay in the start of treatment for teeth. Gaylord and Zajac (2006) investigated the temporal features of alveolar stop consonants uttered by children with VPD. The study aimed to find the relationship between velopharyngeal closing time, VOT and closure duration for the phonemes /t/ and /d/. Nine females and eleven males in the age range of 5 and 11 years were considered. Among these, 13 children had cleft lip and palate and 7 had cleft palate only. Production of syllable /tɅ/ and /dɅ/ by these children were audio recorded. To find out velopharyngeal closure duration, children were asked to produce the word ‘hamper’ five times. It was reported that VOT duration increased as the velopharyngeal closing time increased. However, this trend was not reported for stop gap duration. Based on their results they suggested the need for earlier intervention for children with alveolar clefts. Bechet, Ferbach-Hecker, Sock, Vaxelaire and Stierle (2008) evaluated some acoustic characteristics of speech in eight children with repaired CLP. Their study considered six French plosives in the carrier sentences which were audio recorded. These stimuli were considered for analysis of VOT. It was reported that children with a posterior
cleft palate exhibited significantly longer VOT, with consonants in the varying places of articulation.

The change in VOT before and after surgical correction in children with CLP and TDC was studied in Kannada Language (Gopi Sankar & Pushpavathi, 2014). Five children with unoperated cleft palate in the pre-operative condition and the same children who received palatoplasty surgery were considered in the post-operative group. Eight bisyllabic Kannada words with stop consonants (/p/, /ʈ/, /k/, /b/, /ɖ/, and /g/) were served as test stimuli. The children were asked to repeat the words that were audio recorded. The acoustical analyses were carried out for these words using Praat software. Longer VOT was reported in children with CLP in the pre-operative condition than the control group. And a longer VOT was reported in the post-surgical condition when compared to the pre-surgical condition. Longer VOT in the unoperated children with CLP was attributed to the failure to maintain the intraoral air pressure in the oral cavity.

In contrast, Esghi, Bijankhan, Shirazi and Nourbakhsh (2011) reported that VOT values were found to be similar in the CLP and the normal group. They investigated the effect of place of articulation on voice onset time (VOT) of Persian initial plosive production for Iranian children with CLP in comparison to that of normal children. The study included 15 children with CLP and 20 children without a cleft. The children were instructed to speak seven words in CVC combination. In the study, speech samples were collected using Praat and the children were asked to repeat the words naturally. They analyzed the recorded words for VOT from the spectrogram. Results indicated a similar pattern for, unvoiced plosives /p,t,k/ in both the groups. It was reported that increased VOT values was observed as the place of articulation moved from anterior to a posterior position. For voiced plosives /b,d,g/, the effects of place of articulation on VOT were not found to be significant in both the groups. They concluded that compensatory articulation is an active strategy that the children use to reduce the effect of Velopharyngeal deficiency on VOT.

Deepthi (2008) studied temporal and spectrographic aspects of children with RCLP. Ten children with RCLP in the age range of 5 to 11 years and age and gender matched speech samples of normal children were analyzed. Speech sample consisted of three vowels and twelve words, which were recorded and analyzed. Results
indicated that for fundamental frequency values were found to be higher in children with RCLP compared to the normal children. The format frequencies were reported for F1 (481 Hz, 771 Hz, 485 Hz), F2 (2240 Hz, 1460 Hz, 868 Hz) and F3 (3595 Hz, 2254 Hz, 2798 Hz) of the vowels /a/, /i/, /u/ respectively in children with RCLP. Children with Cleft palate showed relatively higher bandwidths than the normal children for in B1, B2, and B3. Burst duration was reported to be shorter in RCLP than the normal children. She also reported that children with RCLP showed longer VOT when compared to TDC. She also studied consonant duration for Kannada plosives and vowel duration. Results of her study revealed that children with RCLP had longer consonant and vowel duration when compared to that of normal, whereas closure duration was found to be shorter in children with RCLP compared to normals. The increased values were attributed to a reason that children with RCLP could take a longer time to build intraoral pressure which leads to longer duration.

Among the pressure consonants, fricatives are reported to be frequently misarticulated compared to other pressure consonants. Pereira (2009) studied the impact of maxillary advancement surgery on the articulation of /s/ in an individual with CLP using acoustic analysis. Post-operative results after one year indicated a change of center of gravity in the spectrum /s/ in particular towards normal values. Pereira, et al., (2009) investigated the impact of maxillary advancement surgery on the articulation of /s/ in ten individuals with CLP using acoustic analysis. Speech sample consisted of sixty-eight words with pressure consonants combined with four vowels. Speech sample of individuals with CLP was recorded in 0-3 months pre-operatively, 3 months, and 12 months postoperatively. Recorded speech sample was digitized and analyzed using praat software. Post-operative results after one year indicated a change of center of gravity of the spectrum /s/ in particular towards normal values. She concluded that surgery and speech therapy could have brought sufficient changes in the acoustic features in speech in children with CLP.

Subramaniyam, Savitha, and Biji (2011) described the glottal stops using acoustic analysis and they tried to classify the glottal stops in individuals with RCLP across the unvoiced stop consonants in Tamil. A total of eighteen subjects with repaired unilateral CLP participated. They conducted the study in two phases in the first phase wordlist was developed in Tamil and the tokens were recorded in the second phase. Recorded and identified samples were spectrographically analyzed for
acoustic parameters of the glottal stops. Based on the analysis they classified the glottal stops as class A and class B. In class A, glottal stop wave pattern showed synchronized voicing without burst release and in class B, wave pattern showed a delay in voicing with burst release. Closure duration in both classes showed longer duration compared to that of TDC. Burst duration in class B was reported to be within the normal range of the stop consonants. They concluded that acoustic features and subcategories within glottal stops can provide useful information in the assessment and management of children with CLP.

A study in the Indian context by Gopi Sankar and Pushpavathi (2012a) investigated the acoustic changes in the production of sibilant /s/ in children with unoperated CLP (UnCLP) and repaired CLP (RCLP) and compared with that of typically developing children (TDC). The study population included a total of 15 children. This included three groups with 5 children with UnCLP, 5 with RCLP and 5 TDC. Twenty Kannada words loaded with target phonemes (e.g. /kasa/, /sara/ etc) in different positions served as stimuli and were audio recorded. Frication duration was analyzed using Praat software. It was reported that duration of frication of /s/ in children with operated CLP was shorter than the control group and UnCLP. It was also indicated that the frication duration of /s/ varied according to the vowel context and position in the word. It was concluded that in children with CLP due to VPD, adequate air pressure cannot be built in the oral cavity and often it is heard as distorted. Because of this, the child may not be able to build and maintain adequate intraoral pressure to produce /s/ and often the duration found to be reduced.

Gopi Sankar and Pushpavathi (2012b) studied some temporal characteristics of ten children with UnCLP in comparison to the TDC. The speech stimuli included 8 bisyllabic Kannada words loaded with stop consonants. The recorded samples were spectrographically analyzed for the total duration, vowel duration, and closure duration by using Praat software. It was reported that longer vowel duration was observed for voiced consonants compared to that of voiceless consonants. Vowel duration was also found to be prolonged in children with unoperated CLP when compared to that of TDC. The same trend was found even for closure duration and total duration. However, voiceless consonants showed greater closure and total duration when compared to that of voiced consonants. It was concluded that
prolongation was probably used as a compensatory strategy in order to achieve normal production by individuals with CLP which could lead to increased duration.

Zajac, Cevidanes, Shah and Haley (2012) studied to determine maxillary arch size and some spectral characteristics of mid-dorsum palatal stops in English-speaking children with RCLP. Eleven children with RCLP in the age range of 7 and 11 years and eight typically developing children participated in the study. First, spectral moments of /t/ and /k/ contrast words were determined in three groups of children. They analyzed the speech samples of children with RCLP who produced mid-dorsum palatal stops and children with RCLP who did not produced mid-dorsum palatal stops. The first spectral moment for /t/ was lowest for children in the RCLP who produced mid-dorsum stops group when compared to that of RCLP group and typically developing children. They concluded that first spectral moment characteristics of mid-dorsum palatal stop occur with backed tongue placement during stop release.

In another study Gopi Sankar and Pushpavathi (2013) investigated the total duration (TD), closure duration (CD), vowel duration (VD) in five children with unilateral cleft palate pre and post operatively. Eight bisyllabic Kannada words loaded with stop consonants were used as speech stimuli. The data was analyzed spectrographically for the total duration, vowel duration, and closure duration by using Praat software. They reported a longer vowel duration in UnCLP than TDC. It was also reported, that vowel duration was longer in the operated group when compared to that of the unoperated. Voiced consonants showed longer vowel duration compared to unvoiced consonants. Longer closure duration for children with the unoperated group was reported when compared to TDC and operated group. It was also reported that closure duration of children with operated CP was found to be shorter when compared to that of the unoperated cleft palate for all the stop consonants except /ʈ/, /ɖ/. Longer closure duration was reported for voiceless consonants than voiced consonants and a similar trend was observed for children in all the three groups. Total duration for all the target consonants were reported to be longer in the unoperated group when compared to that of the control group. Total duration for /p/, /b/, /ʈ/, and /ɡ/ were reported to be shorter in the operated group when compared to that of the unoperated group. Total duration for /ʈ/, /ɖ/, /ɡ/, and /k/, were found to be longer in operated group when compared to that of the unoperated group.
The authors opined that the primary palatal surgical correction could bring some amount of changes in the temporal aspects of stop consonants.

Eshghi, Zajac, Bijankhan and Shirazi (2013) have conducted a spectral analysis in Iranian children with CLP for word-initial alveolar and velar plosives. Eleven children with repaired bilateral CLP participated in the study. All these children underwent maxillary expansion. Twenty children without any type of oro-facial clefts served as a control group. Nonsense monosyllabic words in CVC combination /tit/ and /kik/ served as a speech sample. They used a Spectral moment analyses (SMA) to depict the production of voiceless alveolar and velar stop-plosives production. Analysis showed that children with CLP had significantly reduced first spectral moments of /t/ and /t/-/k/ difference. They suggested that maxillary arch anomalies could contribute to backing alveolar targets irrespective of any language. To summarize, previous studies related to acoustic analyses in children with CLP have studied VOT, closure duration and on the segmental duration.

2.1.2 Spectral characteristics in children with CLP

Apart from the temporal characteristics of speech that is extracted through acoustic analysis, yet another aspect of acoustic analysis, which provides vital information about speech characteristics, are the spectral characteristics. Very few studies are reported in the literature on spectral parameters of speech characteristics in children with CLP. A study by Hanson (1964) reported the performance of Velopharyngeal closure in children with RCLP. The formant frequencies and amplitudes were measured from the spectrograms. Twenty-eight children with RCLP and twenty-eight typically developing children were considered in the above study. Four vowels /i/, /a/, /æ/ and /a/ were studied in CVC position. Higher formant frequencies of F1 and F2 for the vowel /i/ and /a/ were reported in children with RCLP compared to that of TDC.

Zhang, Guan and Yang (1995) compared the spectrographic analysis of vowel /a/ and /i/ in thirty children with CLP in the age range of 6 to 8 years in the pre and post-operative conditions. Age and gender matched thirty normal children served as their control group. Their results revealed a significant difference between F2 and F3 for /i/ in normal subjects and significant difference in F3 value for /a/ in the pre-
operative condition was reported in children with cleft palate. However, a significant difference was not reported between the values of $F_2$ and $F_3$ for /a/ and /i/ in normal subjects. In the post-operative condition, the results revealed that $F_2$ and $F_3$ values were lower than normal subjects. The authors concluded that spectrographic analysis is a better method to analyze speech of individuals with cleft palate objectively and quantitatively.

Shin et al., (1998) used an objective method to evaluate children with CLP in Korea. They assessed 10 children with CLP as clinical groups and 51 normal children were considered as a control group for their study. The test words consisted of the sustained vowels /i, e, u, o, a/ and for spectrographic analysis /pip/, /pep/, /pup/, /pop/, /pap/ were used. It was reported that children with CLP had shorter sustained vowel duration when compared to that of the normal children. $F_1$ and $F_2$ for vowels were reported to be lower than that of the normal control group.

Few Chinese studies have been reported in the literature highlighting vowels across the pre and post-operative conditions in children with CLP. Xuecai, Ningyi, and Lingxue (2003) studied the formant characteristics of vowels in the speech of individuals with CLP in the post-operative condition with and without speech therapy and were compared to normal children. Results of their study showed that mean value of $F_1$, $F_2$, and $F_3$ showed no difference in the three groups. They also found the significant difference in mean values across control group and pre-speech therapy group and also between pre-speech therapy group and post-speech therapy group. It was reported that the mean values of $F_2$, $F_3$ in post-speech therapy group decreased significantly compared to the control group. The results also indicated that surgical repair of cleft palate does not contribute for achieving perfect Velopharyngeal closure, while speech therapy could improve the closure and articulation. The authors recommended using the spectrographic analysis to document the effect of speech therapy objectively.

Xing-hua, Jai-hua, Li-jun, Wei, and Ya-hui (2003) studied the formants of Chinese vowels in the pre and post-operative conditions in children with CLP and compared with the normal children. They found the location of the first three vowel formants was found to be steady in normal children. The results also indicated that
frequency of the formant was significantly lower in the pre-operative condition compared to the post-operative condition.

In another study, Wang, Jiang, and Huang (2005) analyzed the acoustic features of speech in individuals with a cleft palate before and after surgery. They measured F₁, F₂, and F₃ in 32 individuals with cleft palate during the pre and post-operative conditions. Sixteen normal subjects served as a control group for their study. They found that F₃ values in individuals with cleft palate were significantly lower than the control group preoperatively and a significant difference was not reported for F₂ values in both CLP and control group in the pre-operative conditions. F₃ values in the post-operative condition were found to be significantly higher than the pre-operative condition in individuals with CLP. There was no difference in F₃ value reported in the post-operative condition when compared to that of the normal group.

Chen, Chen, and Guo (2005) studied the correlation between cleft area and compensatory abnormal articulation pattern in seventeen individuals with cleft palate. They measured the cleft ratio and F₁, F₂, F₃ for five vowels /a/, /i/, /o/, /e/, and /u/ and found a significant correlation between cleft ratio and F₁, F₂ and F₃ of vowel /e/ obtained in the pre-operative condition. They also found a positive correlation between F₁ of vowel /e/ and cleft palate ratio in the pre-operative condition. A significant difference was not reported between the pre-operative F₁, F₂, and F₃ of all the five vowels and those of the post-operative condition. They attributed the abnormal articulation pattern in individuals with CLP to the cleft ratio. The authors recommended that greater attention should be given for correcting habituated abnormal articulation habit to get better speech results during speech therapy.

Lima-gregio, Dutka-souza, Marino, Pegoraro-koork, and Barbosa (2010) studied the spectral features of F₁, F₂, F₃, and nasal formant and anti-formant for the vowel /a/ and nasalized vowel at different velopharyngeal port openings produced in the palatal prosthesis used by an individual with velopharyngeal insufficiency. The speech was recorded in a carrier phrase in five velopharyngeal port functioning conditions, prosthesis with no opening, prosthesis with varying opening and without prosthesis respectively. Results of their spectral analysis revealed that F₁ was significantly higher for vowel /a/ when compared to that of nasalized vowel in all the
conditions. It was reported that $F_2$ values for vowel /a/ in varying opening conditions were significantly lowered when compared to other conditions. $F_3$ values were not significant in all the conditions. They concluded that different openings lead to different spectrum measurement but there was no linear relationship detected across the conditions.

Niharika, Tanvi, Navya and Pushpavathi (2012) spectrographically analyzed the spectral and temporal characteristics of the speech of an adult with cleft palate and compared with that of normal subjects. They had considered three subjects with unrepaired cleft of the hard and soft palate, three repaired cleft of the hard and soft palate and six normals as a control group. Among the spectral parameters, they had analyzed first and second formant frequencies, among the temporal parameters burst duration and voice duration were analyzed for words loaded with pressure consonants. Their results revealed, higher F1, increased VOT and burst duration in adults with cleft palate when compared to the normals. They had also observed a significant difference in temporal parameters between repaired and unrepaired group of adults with cleft palate.

Aparna, Sujatha, Sharon and Litna (2012) studied the formant frequencies of $F_1$, $F_2$ for Kannada vowels in individuals with CLP and compared with normal children. The stimuli consisted of three vowels embedded in five target words in the Kannada language. Speech sample was recorded from five individuals with RCLP and five normal individuals. On spectrographic analysis, lower $F_1$ and $F_2$ values were reported for individuals with CLP. They opined that vowel centralization occurs in individuals with CLP but it is not significant for the individuals who attained near normal speech intelligibility. To summarize, most of the previous studies related to spectral parameters studied the first and second formats. There was no consistent pattern observed in the format frequencies of children with CLP.

2.2 Temporal and spectral speech characteristics in typically developing children

Among the temporal parameters, vowel duration was studied extensively across languages in typically developing children. Vowels before voiced consonants were reported to be longer than voiceless consonants which has been widely reported
in the literature (Chen, 1970; House, 1961; Klatt 1973). Raphael (1975) studied the physiological control of time differences between vowels preceding voiced and unvoiced consonants in English. He reported the greater duration of muscular activity in the articulation of vowels preceding voiced consonants. Vowel articulation occurs almost simultaneously in both the voiced and unvoiced consonants. He also reported maintenance of muscular activity in the voiced consonants, relative to the voiceless consonants. Based on the acoustic recording, the results indicated that there were no durational differences between the onset of consonant activity relative to preceding vowel which showed the durational difference between the vowels. He concluded that the acoustically measured durational differences were observed between vowels preceding voiced and unvoiced consonants. Voiced and unvoiced consonants were primarily controlled physiologically by motor commands to the muscles leading to the articulators which are active in the formation of vowels. It was reported that timing of these motor commands, provided by the physiological system for the production of the voiced and unvoiced consonants is reached when the articulatory-muscular activity has attained maximum peak observed for the production of preceding vowel. Even after the production of the vowel, the articulators maintain shapes and positions for the same vowel which lead to longer vowel duration when they precede voiced consonants.

Yet another parameter considered for acoustic analysis is word duration, a segmental duration, which is widely, reported in the literature (Chermak & Schneiderman, 1986; Klatt, 1979; Kubaka & Keeting, 1981; Smith, 1992, 1994; Umeda, 1975). They also reported that motor control improves with age and variability on word duration decreases with age. Research conducted on various aspects of speech segmental duration in children showed greater variability when compared to adult’s speech in terms of formant frequencies, longer in segmental duration and greater variability in temporal and spectral domain ((Eguchi & Hirsch, 1969; Hillenbrand, Getty, Cleark & Wheeler, 1995; Kent & Forner, 1980; Kent 1976; Lee, Potamianos & Narayanan, 1999; Smith, 1978; Smith, Kenny & Hussain, 1996). In the Indian context, several acoustic studies have been attempted (Balasubramanian, 1981; Krishna, 2013; Nagamma, 1988; Rajapurohit, 1982; Sridevi, 2007; Velayudhan 1975) to study the acoustical aspects in the normal individuals.
In the Kannada Language, Savithri (1986) reported that low vowels are characterized by longer duration than a high vowel. She aimed to identify some of the variables affecting the durations of Kannada consonants. She conducted seven experiments, which included the effect of voicing, aspiration, germination, place of articulation, nasality, preceding vowels and effect of gender on the duration of Kannada stop consonants and nasal continuants. The stimuli consisted of 83 meaningful trisyllabic Kannada words including target vowels in the initial position and the above-mentioned consonants in the medial position. Six adult Kannada speakers were asked to read the words, which were recorded for analyses. Results showed the effect of voicing on the duration of consonants where voiceless stops were found to be longer than the voiced stops. Retroflex was found to be shorter compared to palatals and velars. Aspiration, place of articulation, and gender were also reported to have influenced the duration of consonants in Kannada.

Savithri (1996) conducted a study to investigate the preceding vowel duration in six Kannada speaking children. Six meaningful English words with three voiceless unaspirated stops and their voicing counterparts in the final position served as stimuli. Children were asked to repeat six meaningful English words and these words were analyzed using waveform. Results revealed the mean vowel duration was consistently longer before voiced stops than voiceless stops. Among unvoiced, longest vowel duration was observed for retroflex /ʈ/ and in voiced consonants longest duration was observed for velar /g/.

Sridevi (2007) studied the developmental trends of vowel duration (VD) in Kannada speaking TDC. She considered three groups for her study. The groups consisted of children, adolescent, adults and the target words were audio recorded. She reported a decrease in VD from children to adult. She attributed that, the developmental changes were observed more in short vowels than long vowels. In another study, Venkat and Lakshmi (2012) studied the developmental changes in the duration of vowels in Oriya speaking children. Six vowels in VCV bisyllabic words including the bilabials, dental, retroflex and velars were considered. Children in the age range of 3-14 years and ten young adults were asked to repeat the words, which were recorded and analyzed using Praat software. Their results showed that duration
of the vowel reduced with age. Developmental changes in VD indicated differential control over the vowel production in children, adolescents, and adults.

Sridevi and Savithri (1989) studied the temporal and spectral parameters of velar /k/ in the Kannada language in a meaningful word context. An adult was considered as a participant for the study. The target consonants were studied in preceding and following vowel context, following consonant, clustering, and embedding in a sentence. It was reported that the duration of /k/ was longest in the geminate-cluster condition and shortest in the singleton condition. Transition durations and speed of transitions of formants of the preceding vowel decreased successively. The bandwidth and intensities of the F₁ and F₂ declined respectively. They suggested that these spectral and temporal parameters may be affected by the preceding and the following phonemes and also specific to the Kannada language.

Kuijpers (1989) conducted a study on voiced–voiceless distinction in four-year-old children. Six children were considered for their study. Test materials consisted of voiced and voiceless consonants in intervocalic position. Children were asked to name pictures and the recordings were considered for further analysis. Total consonantal duration for back consonant /k/ was lower considerably than front consonants /p/ and /t/. Similar results were observed even for closure duration. Results related to burst duration showed that the dental consonants had longer burst duration compared to /p/ and /k/. They concluded that segmental adjustment system develops towards more of a timed adjustment system with refined motor control.

Closure durations for the syllable in the final stop position are reported to be longer for unvoiced stops than voiced stops (Lisker, 1957; Port, 1978; 1981a). Savithri (1996) conducted an experiment related to closure duration in six children and adults. Eight meaningful words, which consisted of stop consonants in intervocalic position, served as stimuli. They were asked to repeat stimuli and these repeated words were audio recorded for further analysis. Closure duration was measured from the waveform along with the spectrogram. She reported longer closure duration for unvoiced stop consonants than the voiced consonants. Among the unvoiced stop consonants, closure duration for retroflex was found to be longer in all the groups. Dental was found to be the shortest. In the voiced stop consonants, bilabials were found to show the longest closure duration and retroflex /ɖ/ was found
to be the shortest. She opined that during the production of retroflex, an individual has to curl back the tongue and maintain it in the palatal position. However, they may not be able to maintain the curl back tongue in the palatal position for a long time, which leads to quick articulatory release. This, in turn, results in shortening of the retroflex consonants.

Among the temporal parameters VOT was studied widely across the language in TDC (Abramson & Lisker, 1965; Fant, 1980; Lisker & Abramson, 1964; Savithri, 1996; Shukla, 1989; Sreedevi, 1990; Williams, 1977). Stevens & Klatt (1974) reported that duration depends on the movement of the articulator that forms the closure. It is more for tongue body, less for tongue tip and least for the lips. The increase in the time taken for consonant release leads to increase in the time taken for the development of trans glottal pressure drops sufficient to initiate voicing an increase in VOT.

Shukla (1989) studied VOT in thirty normal individuals in the Kannada language. Stimuli consisted of bisyllabic words with stop consonants in the initial position. Results of his study showed that all the voiceless stop consonants have positive VOT and mean VOT increased in duration as the place of articulation moved from bilabials to velars. Voiced consonants showed negative VOT. Savithri (1996) and Savithri, Pushpavathi and Sujatha (2007) analyzed VOT in voiced and unvoiced stop consonants in Kannada. Children were asked to repeat six meaningful Kannada words and repeated words were audio recorded and analyzed using spectrograms. They that voiced stops showed lead VOT and voiceless stops showed lag VOT. Among voiced stop consonants, velars showed longer VOT followed by dental and bilabials and similar results were reported even for unvoiced consonants. She also reported that average VOT values declined in older children compared to younger children.

Acoustic and spectral characteristics of fricatives were other aspects studied and reported widely in the literature. Studies have found that spectral moment data on the acoustic signal of adult fricatives/plosives productions are characterized by distinct spectral patterns of the acoustic energy (Forrest et al., 1988; Jongman et al., 2000). Secondary associated area of the research has utilized spectral moment’s analyses to look at the acoustic features of stops/fricatives change as a function of
normal speech development and aging (Forrest et al., 1990; Nittrouer et al., 1989; Nittrouer, 1995). Nissen and Fox (2005) studied the acoustic features of unvoiced fricatives produced by adults and TDC from three to six years of age. Recorded samples were analyzed for multiple acoustic parameters such as durations, spectral slope, and variances in spectral moments. It was reported that adults showed relatively shorter fricative duration compared to children.

Fant (1960) determined that scale factor for $F_1$ and $F_2$ were low for rounded back vowel and a higher $F_1$ was observed for open front and back vowel. He also pointed out that these differences were consistent with a difference in the vocal tract anatomy between males and females. Sundberg (1969) opined that the articulation in the configuration of the vocal tract gave rise to the variation in ranges of formant frequencies. A change in the shape and extent of the opening of lips, the placement of the tongue, mandible, and soft palate have been considered to contribute to the changes in the responses of the cavities in the vocal tract to different frequencies and thus changes in the formant frequencies.

Eguchi and Hirsh (1969) studied the vowel formant frequencies in seventy children and adults for six different vowels. The developmental trend appeared more strongly when children and adults were compared. They noted lowering in average $F_1$ and $F_2$ as a function of increasing age, which was attributed to a generalized lengthening of the vocal tract. Children had average $F_1$ values equal to those for females. Variability of the formant frequencies was higher for mid vowels than for high front and high back vowels. However, the variability was found to decrease with age. Variability was found to be more for vowel /a/ than vowel /i/ and /u/. Their results were not generalised as the number of subjects and age of the subjects were not provided.

Considering the above point Bennett (1981) studied the vowel formant frequencies characteristics of five vowels in forty two children in seven and eight-year-old boys and girls. Vowel formant frequencies were estimated directly using broadband spectrograms. Results of their study showed that the vowel formant frequencies of male children were found to be lower than females and the extent of gender differences varied as a function of formant number and the vowel category. Lee et al., (1999) found that differences across gender were not evident until around
age 15 years for $F_2$ and $F_3$. Busby and Plant (1995) reported that the $F_1$ values were higher for females than males in low vowels and higher $F_2$ for all the vowels. Bennett (1981) indicated that the differences across gender seen in children are mainly due to the differences in the pharyngeal length.

Hillenbrand, Getty, Clark and Wheeler (1995) aimed to replicate and extend the classic study of vowel acoustic by Peterson and Barney (PB, 1952). Recordings were taken from forty five men, forty eight women and forty six children producing the twelve vowels in h-V-d syllables. Their results showed differences between these measurements on average formant frequencies in $F_1$ and $F_2$ compared to PB study. They concluded that these differences observed may be due to the changes that occurred in the regional dialect over decades.

Formant frequencies have been studied extensively in the Indian languages such as Rajapurohit, (1982); Sridevi (2000); Venkatesh (1995) in Kannada, Krishna (2009) in Telugu, Ganesan, Agarwal, Ansari and Pavate (1985) in Hindi. Sreedevi (2000) studied the acoustic features of vowels in Kannada in three age groups. She considered thirty participants in 6-9 years, 14 -15 years and 20- 30 years ten from each age group. She reported that boys showed higher $F_1$ than girls by 3%. Adolescent females showed higher $F_1$ in (7%) compared to adult males (11%). $F_2$ for females was significantly higher compared to males across groups. A linear decrease in $F_3$ was observed across groups and a further significant decrease in $F_3$ was also observed for adults across gender. It was also reported that formant frequency values in children decreased with increase in age. She attributed that the difference was not only due to anatomical differences but also due to differences related to the pharyngeal to oral cavity area.

Krishna (2009) studied the acoustic features of vowels in Telugu in 72 normal speaking individuals in three different age range from 06 to 09 years, 13 to15 years, and 20 to 30 years. Recorded words were analyzed using Computerized Speech Lab 4500. Their results related to formant frequencies showed that $F_1$ for the low-mid vowel /a/ and /a:/ had highest mean $F_1$ then back high vowels /u/ and /u:/ central vowels had higher mean $F_1$ followed by front and back vowels. In $F_2$, long vowels showed higher mean $F_2$ than short vowels. High vowels /i/ and /i:/ showed the highest mean $F_2$ and back high vowel /u/ and /u:/ found to have the lowest. As seen in $F_2$,
similar results were observed for F3. He also studied the vowel formant bandwidth in Telugu and reported that bandwidth was found to increase with an increase in formant frequency for all the vowels in Telugu. The vowel /a/, it was observed to be 57.71Hz, 137.11Hz, 228.30 Hz for B1, B2, B3 respectively.

To summarize, the acoustical analyses related to temporal and spectral parameters are studied and reported extensively in the typically developing children. However, high degree of variability is reported in the acoustical studies of children’s speech as found in the studies by (Eguchi & Hirsh, 1969; Hillenbrand et al., 1995; Kent & Forner, 1980; Kent, 1976; Savithri, 1996; Sharkey & Folkings, 1985; Smith et al., 1995; Smith, 1978, 1992; Tingly & Allen, 1975). Acoustical parameters studied in children with CLP showed greater values on the temporal parameters when compared to normal children. However, most of the studies have been conducted in children with RCLP condition in the post-operative condition. Hence, the current study was undertaken to examine the acoustical parameters in children with CLP before (pre-operative condition) and after surgery (post-operative condition).

2.3 **Perceptual speech characteristics in children with CLP**

Apart from acoustical analyses of speech, perceptual speech characteristic of speech in children with CLP have also been extensively reported in the literature (Harding & Grunwell, 1998; McWilliams et al., 1971; Sell & Grunwell, 1990; Trost, 1981, 1990). They are hypernasality, nasal air emission, weak oral pressure consonants and compensatory articulation. Hypernasality is defined as undue nasal resonance perceived on vowels and sometimes on voiced consonants. Nasal air emission is defined as the audible leak of air through the nasal tract observed during the production of high pressure consonants (McWilliams et al., 1990). A weak oral pressure consonant (WOPC) is defined as a general loss of energy observed during the production of high-pressure consonants. WOPC and nasal air emission occur secondary to the open velopharyngeal port and impairment of all these can lead to the development of compensatory articulation.

Compensatory articulations commonly observed in individuals with CLP and velopharyngeal dysfunction have been described radiographically and with respect to perceptual characteristics and articulatory gestures by Trost (1981). She has explained
and defined pharyngeal stop, mid-dorsum palatal stops, and the posterior nasal fricative radiographically to depict the deviant place of production. However, very few reports are available on speech characteristics in children with unoperated CLP and compensatory articulation.

A study by Landis and Pham (1974) has reported articulation error patterns and speech intelligibility in fifty-four Vietnamese children with unoperated oral clefts. These children were divided into three subgroups. The first group consisted of twenty-one children with an unoperated cleft of the lip and palate and the second group consisted of eighteen children with repaired lip and with or without overt cleft of the alveolus and unrepaired cleft of the hard and soft palate. The third group included fifteen children with an unrepaired isolated cleft of the palate. The speech of these children was assessed using Vietnamese articulation test and sentences repetition task. Nasality and speech intelligibility were also analyzed using the rating scales. Articulation errors were reported to be more in the first group compared to the other groups. Nasality and speech intelligibility scores were found to be better in group 3 compared to groups 1 and 2. Glottal stops and pharyngeal productions were reported to be seen in groups 1 and 2. Group 3 showed more of weak production and omission.

Fletcher (1985) reported that in adult individuals with unoperated cleft palate use oral/pharyngeal muscles to produce the oral consonants. Trost-Cardamone (1990b) reported that hypernasality, nasal air emission, and reduced intra-oral pressure were unavoidable speech characteristics of individuals with unoperated cleft palate. Sell and Grunwell (1990) reported speech in unoperated Sinhalese individuals with cleft palate over the 8 years of age. She reported that these children mostly produced glottal and pharyngeal articulation. Lee (2001) analyzed the speech of Nepali individuals with unrepaired cleft palate using Euro cleft phonetic framework. The study consisted of sixteen subjects with unilateral, bilateral and submucous clefts. Individuals were asked to imitate trisyllables, single, nonsense syllables, rote count, and picture naming with 26 Nepali consonants. These were recorded and subjected to analysis. Results revealed that errors such as nasal air flow, glottal realization, alveolar deviations, and sibilant deviation were observed in Nepali individuals with cleft palate. However, three important characteristics, including weak consonants,
consonant deletion and realization as /h/ were not included in the Eurocleft framework.

Apart from the perceptual evaluation, few groups of researchers have conducted electropalatography study to understand the production of speech in children with CLP. Gibbon (2004) investigated to understand the abnormal tongue-palate contact in the speech of individuals with CLP using Electropalatographic (EPG) data. Research related to EPG in children with CLP is widely reported in the literature in English (Gibbon & Hardcastle, 1989; Gibbon & Crampin, 2001). Michi, Suzuki, Yamashita, and Imai, (1986); Yamashita Michi, Imai, Suzuki, and Yoshida, (1992) have studied the speech characteristics in fifty-two Japanese individuals with CLP. Results showed retracted placements to be most frequently occurring EPG pattern in Japanese individuals with CLP. Similarly, Whitehill, Stokes, Hardcastle and Gibbon (1995), Whitehill, Stokes, and Yonnie, (1996) have studied the speech characteristics in Cantonese individuals with CLP. She reported eight abnormal EPG patterns of tongue-palate contact in persons with RCLP based on the available data. First, was reported to be increased abnormal tongue-palate contact, the second retraction to palatal or velar contact under this overuse of the tongue dorsum was reported. The third pattern reported was front placement and under this, she also reported of reduced alveolar-velar placement separation. The other patterns observed were a complete closure, open pattern, double articulation and increased variability in EPG pattern last as abnormal timing for articulation in EPG.

Outcome studies on secondary palatal surgeries are widely reported in the literature. However, outcome studies on primary palatal studies are limited. Lohmander-Agerskov (1998) conducted a study to find out speech outcome following cleft palate surgery with the Goteborg regimen with delayed hard palate closure. The speech of 38 children with unilateral CLP and 21 children with bilateral CLP were evaluated. For the perceptual assessment, they had considered sentences and spontaneous speech for recording. The results of their study showed the low occurrence of hypernasality (8% only in five children) in children who underwent pharyngeal flap and hard palate closure surgery. It was also reported that 10% of the children exhibited primary velopharyngeal insufficiency. Errors related to glottal articulation was found in three children with bilateral clefts who were in the preschool
age. However, children with unilateral cleft did not exhibit these errors. They concluded that backing articulatory errors was considered as a problem. To improve their outcome they decided to modify slightly the surgical closure method for the soft palate and to place the vomer flap further anteriorly to provide a narrowing of the cleft in the hard palate, and they suggested closing the hard palate at 3 years of age.

Khosla, Mabry and Castiglione (2008) retrospectively reviewed the primary surgical speech outcome of the furlow z plasty. They reviewed 168 children who underwent furlow palatoplasties in their center. Out of 168 children, 140 children were considered based on the review. Speech assessments were performed for hypernasality, nasal air escape, articulatory errors and velopharyngeal function. Their results revealed that out of 140 children, 83% of children did not exhibit hypernasality, 84% of children did not show any sign of VPD, with respect to nasal escape, 90% showed no escape of air and 69% showed no articulation errors. Only 2% of the population required secondary surgery in the selected population. They concluded that improvement observed may be due to the influence of speech therapy carried out in their center after surgery.

Murthy, Sendhilynathan, and Hussain (2010) compared the pre-operative and post-operative speech results of Tamil speaking individuals older than 10 years of age who underwent primary palatal repair. Their study considered 131 individuals with the different types of cleft who underwent cleft palatal repair with two flaps technique. Articulatory errors, nasal air emission, hypernasality, and intelligibility were assessed before and after the surgery. The speech sample consisted of sentences and phonation of vowels. Analysed speech sample results revealed a significant improvement in the articulation, resonance, and speech intelligibility postoperatively. They concluded that late primary palatal repair showed improvement in overall speech aspects.

It can be observed from the above studies that perceptual analysis of speech is considered as the main assessment procedure for speech outcomes associated with cleft palate. However, reporting these speech outcomes in children with CLP was challenging for the professionals involved in the team. There is extensive research that has focused on studies related to inter-subject and intra-subject variability and has
discussed the role of many variables such as the type of the stimuli, judges, type of rating scale used in the analysis of the speech of CLP. McWilliams et al., (1990) stressed on the need for reliable and detailed perceptual speech data and suggested that data should be supported by instrumental evaluation. Researchers like Kuehn and Moller (2000), Howard and Heselwood (2002) supported perceptual analysis as essential measure along with instrumental analysis. However, McComb (1989) suggested that a standardized speech assessment should be developed at international basis which would be helpful in inter-center comparison of data.

Grunwell et al., (1993) explained the general principles to be adopted during perceptual assessments in the clinical context. Lohmander and Olsson (2004) have reported of rating scales that can be used for perceptual analysis in the speech of CLP. They indicated that, scales which are used for perceptual analyses do not provide adequate information on the items to be collected in sample data. They also indicated there are huge differences in the way collected data analyzed related to speech of person with CLP.

There have been arguments and controversies about the parameters that should be considered for measurements of speech in persons with CLP. Dalston et al., (1988) suggested that articulation, hypernasality, hyponasality, nasal escape, speech intelligibility have be considered in the protocol. Witzel (1991) suggested that speech intelligibility have to be reported with the combination of consonants and resonatory characteristics. Sell et al., (1994) and Witzel (1991) reported that, one should be cautious while reporting on intelligibility, because it is hard to rate consistently. It can be affected by many factors such as articulatory errors related to hearing, developmental errors, and experience of the rater. A study by Whitehill et al., (2002) has emphasized a need for global measures of speech performance with a detailed quantitative methodology. Lohmander and Olsson (2004) have recommended that resonance, nasal airflow, and consonant production should be considered for the evaluation of speech outcome studies. Disagreements in studies are also prevalent about the scales that are used to assess the different speech parameters in CLP.

There have been a number of scales developed and used for the perceptual assessment of speech parameters in children with CLP. Pittsburgh Weighted Speech
Scale, a global rating scale was developed by McWilliams and Philips (1979) and by McWilliams et al., (1981). The scale consisted measurements of ratings for nasal air emission, facial grimace, nasal resonances, phonation, and articulation. Based on the total scores obtained, efficiency of velopharyngeal valving function was interpreted. The velopharyngeal function was assessed based on the scores and intraoral inspection. However, Pittsburgh Weighted Speech Scale and the categorical approach for assessment of articulation problems in the CLP (Ainoda & Okazaki, 1993) focused only on Velopharyngeal function, with minimal details recorded about consonant errors. Temple Street scale was developed by Sweeney (2000). It was developed to assess the errors related to resonance and nasal airflow. However Temple Street scale does not include the assessment of the consonants errors, but it provides information about the hypernasality, hyponasality, and nasal airflow errors and this has been tested for validity and reliability.

Euro cleft speech group was developed to facilitate and document the cross-linguistic speech outcomes across five northern European languages (Euro cleft Speech group, 1994; 2000). However, this was developed specifically for older children to provide a detailed analysis of the phonetic characteristics of speech. The Great Ormond Street Speech assessment was developed as a standardized and comprehensive method of perceptual assessment. It was developed to assess the speech of individuals with CLP in clinical settings at UK cleft canters with good levels of Interrater reliability (Sell et al., 1994, 1999).

Several studies have reported a number of factors, which affect the speech outcome assessment in children with CLP. Reliable and detailed perceptual speech sample data are required for the analysis as reported by McWilliams et al., 1984; 1990; and Kuehn and Muller, 2000. Use of common terminologies and their description are rarely included in the cleft palate measures (Kent et al., 1999 and Whitehill, 2002). Other issues such as reliability and validity of the assessment methods are not often reported (D’Antonio and Scherer, 1995; Lohmander and Olsson, 2004; Wyatt et al., 1996).

Sell (2005) reviewed issues related to the perceptual analysis of speech in individuals with CLP and associated disorders. She opined that assessment at the problem level requires extremely trained professional and systematic method of data
sampling, acquiring, and documentation. She also reported consistent method to analyze the sample and understanding the results accordingly. It is suggested that outcome measure should also provide information on functional issues that affects the quality of life in individuals with CLP. Whitehill (2000) conducted a review of the literature on assessing intelligibility in individuals with cleft palate from fifty-seven articles related to speech intelligibility. It was reported that most of the studies used similar measures i.e., rating scales used for assessing speech intelligibility. Her review study raised concerns related to reliability and validity of the measurement being used, terminologies, and factors contributing to affect the speech intelligibility.

Van Lierde, De Bodt, Borsel, Wuyts and Cauwenberge (2002) studied the effect of cleft type on speech intelligibility in 37 children with unilateral and bilateral cleft lip and palate. All the children had undergone the same surgical protocol. To find out the effect of cleft type and to measure, they used objective and subjective assessment techniques. In the objective assessment, nasometer and the mirror fogging tests were used to quantify the nasal resonance. The perceptual assessment of overall speech intelligibility was assessed using 4 point rating scale. The stimuli considered were spontaneous speech, reading and repetition of the sentences. Results showed no difference in nasalance values, nasality and overall speech intelligibility across the type of cleft.

Considering the above issues few universal reporting perceptual scales are developed recently. These scales are developed such a way that it can be used within and across languages, at different centers, and in other countries. Considering the above, Cleft audit protocol for speech-augmentation (CAPS-A) was developed by John, Sell, Sweeny, Harding-Bell, and Williams (2006). This was developed mainly to address the inter-center audit studies of cleft speech and to test its acceptability, validity, and reliability. They have conducted the study in three phases, the first phase was on the development of the tool and second phase assesses the face and content validity of the developed tool. The third phase was an assessment of validity and intra and inter-reliability and acceptability. This system defined cleft type speech characteristics based on the principle of traffic light system, which gives information on both speech outcome and potential intervention needs. Green indicative of a satisfactory result with no treatment needed and yellow signifying that there is a need
to monitor the progress. The children may have to undergo for some amount of management, which can be surgical, or speech therapy intervention. Red indicated an unsatisfactory result, which requires entire assessment and management. The developed system had adequate levels of validity and with moderate to very good Interrater reliability. Raters reported that the CAPS-A was acceptable and easy to use with appropriate training. This system has a number of detailed audit measures, which can be used for auditing across centers and across countries.

Scand cleft speech project group developed a methodology for a speech assessment. Speech samples, recordings, and method of analysis were developed for the cross-linguistic study and Lohmander et al., (2009), tested the same in a pilot study. Speech assessment in the Scand cleft found to be dependable and suitable for cross-linguistically. However, sometimes it is hard to track and requires further modification in the analyses method. Presently available methodologies on perceptual speech analysis focused on speech as a primary outcome. Hence, the studies should include, SLP’s as a member while collecting data, analyses and for further intervention.

Considering the above points, universal speech parameters for detail analysis of speech outcomes for individuals with CLP was developed by Hennningson et al., (2008). They have developed a set of five universal speech parameters. These parameters included consonant production errors, resonatory characteristics such as, hypernasality, hyponasality, audible nasal air emission and voice disorders. Speech understandability and acceptability as global parameters were also included as they suggested that they can be reported for any type of speech disorders. Apart from these parameters they have also explained in detail the parameters and guidelines for speech sampling content materials for the assessment. They have also explained the scoring procedure with respect to the considered parameters.

Lohmander (2008) reported that universal speech parameters system uses a minimal standard protocol that is simple to comprehend, and easy to evaluate across languages, and across various centers. Another study by Benjamas, Preeya, Daranee, and Netra (2011) aimed to adopt universal report system in Thai speech parameters for individuals with cleft palate. Development of assessment materials in Thai was prepared by an experienced Speech-Language Pathologist using the speech sampling
guidance provided in universal parameters. They have validated the developed materials by administering it to 16 children with CLP. Results showed that Thai speech parameters exhibited with seven typical speech characteristics of individuals with CLP. Their study results showed high to a large percentage of agreement for most of the speech parameters. They concluded that test may be recommended as a universal standard as a methodological approach while reporting audit and research outcome. They also recommended that training program to be provided to the raters to improve their listening skills on the identification of the articulatory errors in children with CLP.

Very few studies have been conducted with respect to the type of speech materials used in the evaluation of CLP. A study by Klinto, et al., (2011) studied the effect of speech in different context on speech judgment in five-year-old children with and without cleft palate. Single word naming, sentences repetition, narrative (retelling) and conversational speech were used as materials for assessment. Judges were asked to rate for a percentage of correct consonants, correct place, and manner, active cleft speech characteristics. Results revealed active cleft speech characteristics, percentage correct consonants, places, manner and phonological simplification processes were found to be correct in word naming than all other speech stimuli in children with CLP. They concluded that word naming was found to be most reliable speech material compared to other materials that can be considered with good Intra and inter-judge reliability.

Gnanavel and Pushpavathi (2012) studied the influence of type of cleft and speech stimuli on the perceptual rating of speech intelligibility in twenty individuals with CLP in the Kannada language. They considered children with repaired CLP, repaired cleft palate, repaired submucous palate and unrepaired cleft palate in equal numbers. The stimuli consisted of ten (five oral and five nasal) sentences and ten words loaded with pressure consonants. Recorded samples were given to four Speech-Language Pathologists for speech intelligibility rating using a 5 point rating scale. Their results showed that there was no difference across different variety of cleft and type of the stimuli. They suggested spontaneous speech or connected speech may be considered for the assessment of speech intelligibility in individuals with CLP.
To summarize, there are limited number of studies reported in the literature on the acoustic analyses of speech in individuals with a cleft palate before and after surgery. As a part of the acoustic analyses, most of the available reported studies are restricted only to study the formant frequencies of vowels and VOT in persons with CLP. However, there are no studies, which give detailed information on acoustic analyses of temporal and spectral parameters of speech characteristics in children with CLP pre and post surgery and their comparison with TDC. Similarly, there are very few studies reported on perceptual speech analyses of individuals with cleft lip and palate before and after surgery. In perceptual analyses, reported studies are limited to pre or post-operative speech characteristics and have used varied methods for perceptual analysis. However, there are no Indian studies, which provide insight into the detailed acoustic and perceptual analyses of speech in children with CLP. Hence the present study was initiated to explore the changes in the acoustic and perceptual speech characteristics in children with CLP across pre and post-operative conditions and to compare with TDC.