CHAPTER V

DISCUSSION

The aim of the present study was to investigate some acoustic and perceptual speech characteristics in children with cleft palate before and after primary palate surgery and to compare with typically developing children. The acoustic analyses of speech were carried out by measuring temporal and spectral parameters. The overall mean scores were calculated based on the spectrographic measurements of the recorded speech samples from TDC and children with CLP. Temporal and spectral parameters from speech samples were analyzed across gender, condition and the type of stimuli for the target pressure consonants.

Results of the present study indicated several points of interest. There was no significant difference observed across conditions in temporal and spectral parameters. However, the findings of the present study indicated that children with CLP showed longer vowel duration (VD), total duration (TD), closure duration (CD) and voicing duration in the pre-operative condition when compared to the post-operative condition. This may be due to the compensatory mechanism used by children with CLP while using the oral/pharyngeal muscles to achieve the normal oral production, which can lead to longer duration as reported by Fletcher (1985). Moreover, in the present study, most of the temporal parameters were observed to be longer in the pre-operative condition, which was noted for the target consonants present in the medial position. Another reason could be that in order to achieve the normal production, children with CLP in the pre-operative condition may prolong the vowel in the preceding position, which leads to longer VD, TD, and CD in the pre-operative condition.

Children with CLP in the post-operative condition showed longer word duration (WD), syllable duration (SD), burst duration (BD), and frication duration (FD) when compared to that in the pre-operative condition. This may be due to prolongation of the segmental duration as a purposeful feature used to compensate for damped sound energy (Forner, 1983). It was also reported 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 of the target phoneme (Forner, 1983). In the present study, temporal and spectral parameters were compared across the pre and post-operative condition in children with CLP. Results showed that there was no significant difference for all the temporal and spectral parameters studied in the present study. Thus, the first hypothesis can be accepted as there was no significant difference found between the pre and post-operative conditions in children with CLP for all the temporal and spectral parameters.

Second, results of the current study indicated that children with CLP exhibited longer word, syllable, vowel duration, total duration, closure duration and affrication duration when compared to that of TDC. This may be due to the fact that an individual with CLP uses comparatively higher levator veli palatine activation levels for speech when compared to the normal individuals (Kuehn & Moon, 1995). As indicated by Kuehn and Moon (1995), individuals with CLP may require greater effort to achieve velopharyngeal closure. Due to greater effort during VP closure, individuals with CLP may be exhausted during the continuous speaking task. In order to avoid this exhaustion, individuals with CLP may reduce both the level and speed of velar displacement, which in turn could lead to prolonged duration (Kuehn & Moon, 1995). Another reason could also be attributed to the inability to sustain intraoral pressure due to nasal air emission in children with CLP, which can lead to a longer duration in an attempt to rebuild sufficient intraoral pressure to produce the consonants (Forner, 1983; Tarlow, 1974; Warren & Mackler, 1968).

In the present study, vowel duration was found to be significantly longer across groups for all the consonants. A study by Casal et al., (2002) reported that vowel /a/ was most prolonged compared to other vowels. They also reported that duration of stressed vowels with a tonic accent in Spanish was more prolonged which is indicative that vowel positions also play a role in altering vowel duration. Yet another study Bechet et al., (2008) reported that vowel /a/ had a longer duration in children with CLP when compared to that of normal children. Casal et al. (2002) reported that prolongation of vowel duration may be due to a wider opening of the mouth by children with CLP which could have lead to prolonged duration of the vowel. Children with CLP are often observed to use abnormal mouth opening, which in turn lengthens the vowel duration in order to be understood by the listener. Children with CLP may use prolongation of the vowel as a compensatory mechanism.
to achieve a normal production of the target word/syllable, which can lead to longer
duration. Findings of the current study related to prolonged consonantal duration in
children with CLP was found to be in consonance with the study by Bechet et al.,
(2008); Casal et al., (2002); Chen et al.,(2005); D’ Antonio (1982); Gopi Sankar and
Pushpavathi (2012); Ha, Sim, Minje and Kuehn (2003).

Closure duration and total duration were yet other parameters, which showed a
longer duration in children with CLP when compared to TDC in the present study.
Forner (1983) and Tarlow (1974) reported that longer duration in CD and TD can be
attributed to exaggerated laryngeal gestures used as an alternate mechanism for a
decrease in oral pressure in children with CLP. Findings of the present study are in
support with Chen et al., (2005); Forner (1983); Gaylord and Zajac (2006); Gopi
Sankar and Pushpavathi, (2012); Pushpavathi and Navya (2013); Subramaniyam,
Savitha and Biji (2011). It is often observed that CLP speaker seem to use
prolongation as a compensatory strategy to achieve a normal production, which can
lead to longer duration (Forner, 1983). Hence longer CD and TD observed in children
with CLP in the present study.

In the present study, another temporal parameter i.e., the affricate duration was
also found to be longer in children with CLP across conditions compared to TDC.
Warren and Forner (1983); Mackler, (1968); Tarlow, (1974); Vasanthi (2001)
reported that children with CLP are not able to sustain and maintain their intraoral
pressure and are not able to sustain because of the nasal air emission. They reported
that individuals with CLP could be taking a longer duration to rebuild sufficient
pressure that is required to produce for the release of a plosive or affricates, in turn
leading to longer duration.

Thirdly, the findings of the present study indicated that children with CLP
exhibited shorter VOT for voiced consonants, VoD, burst duration, and frication
duration compared to that of TDC. Shorter VOT in children with CLP could be
attributed to VPD. The soft palate and posterior pharyngeal wall contact during the
production of speech can be possibly affected by palatal surgery (Van Lierde et al.,
2002; Mora et al., 2007 & 2009). These surgical procedures are reported to change the
velar length, thickness, and consistency. Palatal surgeries are sometimes reported to
leave scars and tighten the soft palate muscles and tissue, which may lead to
shortening of the soft palate. Because of this, a child with CLP may not be able to sustain intraoral air pressure for a long time in the oral cavity leading to a shorter VOT. Results of the present study are in support of the findings of various other studies reported by Bechet et al., (2008); Casal et al, (2002); Gaylord and Zajac (2006); Vasanthi (2001).

In the present study, it was observed that VOT for voiced consonants was found to be longer in TDC when compared to that of children with CLP in the pre and post-operative conditions. This is attributed to a possible use of compensatory articulation used by children with CLP as an active strategy to decrease the effect of velopharyngeal deficiency on VOT (Gamiz, Calle, Amador & Mendoza, 2006). Further, Gamiz et al., (2006) also reported that, in the absence of the compensatory articulation, VPD can lead to a reduction in intraoral pressure, as a result of this an increase in subglottic and supraglottic pressure difference could be observed. Because of these pressure differences, vocal folds continue to vibrate till the pressure differences reach zero, which leads to longer VOT. However in the present study, VOT was found to be decreased for voiced consonants. This indicates that children with CLP are unable to maintain the intraoral pressure for a longer time which in turn could lead to a decreased VOT. Variability in the results of VOT may be due to the incoordination between the laryngeal and supralaryngeal gestures and achieving typical valving might not be an easy task for children with CLP as reported by Whiteside et al., (2003).

In the present study, VOT increased as the place of articulation moved backward in the oral tract in case of unvoiced stop consonants, which was observed across groups. Fant (1980) and Stevens and Klatt (1974) reported that duration of voiced and unvoiced consonants depends on the movement of the articulator that forms the closure. They reported duration to be more for tongue body, less for tongue tip and least for the lips. During the production of unvoiced stops, voicing starts only when a transglottal pressure drop is enough to initiate voicing after the articulatory/burst release. VOT is increased as the place of articulation moved backward in the oral tract in case of unvoiced stop consonants. The increase in the time taken for consonant release can lead to an increase in time taken for the development of trans glottal pressure drop, which is enough to initiate voicing and
increase the VOT. Hence, VOT is shorter for bilabials and longer for velars. The word duration and burst duration parameters also showed a similar trend as the place of articulation moved from bilabials to velars. These findings are in consonance with the results of Basu (1979); Esghi, Bijankhan, Shirazi and Nourbakhsh (2011); Lisker & Abramson (1964, 1967); Rajeev, Pushpavathi, and Savithri (1995); Savithri, Pushpavathi, Sujatha (2007); Shukla (1969); Sridevi, (1990). However, this result was in contrast to the results of Kushal raj and Nataraja (1984) where they used small phrases as stimuli for the measurement of VOT. Hence, the difference in VOT was observed compared to the other studies.

Frication/fricative duration (FD) in the pre and post-operative condition was found to be shorter compared to TDC. Pereira (2009) reported that the duration depends on the amount of air available, the degree of VPD and position of the tongue for the production of the fricative. Due to VPD, an adequate air pressure cannot be built in the oral cavity and often it is heard in a distorted manner. Hence, the child with CLP is unable to build and maintain adequate intraoral pressure to produce fricatives. Hence often the frication duration was also reported to be reduced in children with CLP. Results of the present study related to FD, support the findings of Gopi sankar and Pushpavathi (2012); Nissen (2003); Pereira (2009).

In the present study, syllable duration, closure duration, and total duration were found to be decreasing as the place of articulation moved backward in the oral tract. This may be related to the vocal tract physiology of young children as reported by Lieberman et al., (1972) i.e., the sounds produced from the back of the oral cavity require less activity, less time and less refinement than sounds articulated in front of the mouth with the tip of the tongue or the lips. Results of the present study were in consonance with a study by Kuijpers (1989) who reported that total consonant duration for the back consonant /k/ differed significantly for both front consonants /p/ and /t/. As observed from previous studies, closure duration of /k/ was found to be shorter and longer for /p/ and /t/. A similar result was found in the present study as well. An Indian study by Rajeev, Pushpavathi, and Savithri (1995) also reported similar results in Kannada speaking typically developing children for closure duration. Their results revealed that closure duration was longer for voiceless stops than voiced stops and closure duration was found to be decreased when the place of articulation moved backward in the oral tract (bilabials to velars). They reported that
increase in the closure duration may be due to the high articulatory resistance in case of voiceless stop consonants which tend to increase the duration of the closure.

Fourthly, the spectral parameter $F_1$ for the low-mid vowel /a/ was found to be higher in pre-operative condition when compared to that of the post-operative condition. A vowel formant frequency for $F_1$ depends on the tongue height and in the present study higher $F_1$ was observed among children with CLP in the pre-operative condition. Similar findings were observed when pre-operative condition compared with TDC. This could be due to a pharyngeal constriction used by children with CLP in the pre-operative condition as a compensatory strategy which could have led to a higher $F_1$. Also, in the present study, $F_1$ was found to be lowered in the post-operative condition when compared to the pre-operative condition in children with CLP. Similar findings were observed when post-operative condition compared with TDC. This could be possibly attributed to the active use of tongue by children with CLP in order to bring adequate velopharyngeal closure which can result in lower $F_1$.

The results of the present study also indicated that in the post-operative condition, children with CLP exhibited higher $F_2$ for the low-mid vowel /a/ compared to that of pre-operative condition except for /t/, /g/ and /m/. $F_2$ of the low-mid vowel /a/ was found to be higher in children with CLP in the pre-operative condition than TDC except for /ʃ/, retroflex, velars and fricatives. Whereas, children in the post-operative condition showed higher $F_2$ for low mid vowel /a/ than TDC for all consonants, except for /t/, /g/ and retroflex. It is understood that a vowel formant frequency for $F_2$ varies with tongue advancement. In the present study, a higher $F_2$ was observed in children with CLP in the post-operative condition. This could be due to varying of the tongue height and jaw movement using abnormal articulatory pattern to compensate for the target sound production which narrows the region of the oral cavity. Results of the present study are in consonance with previous studies by Casal et al., (2002); Fant (1970); Fujimura (1960); Hanson (1964); Navya and Pushpavathi (2011) and Vasanthi (2001).

They reported of a higher $F_1$, $F_2$ for vowel /a/ in children with CLP. In the post-operative condition children with CLP exhibited higher $F_3$ for low mid vowel /a/ compared to that of the pre-operative condition except for /p/, /tʃ/, /g/ and dentals (/t/, /d/). Higher $F_3$ was found in TDC compared to that of pre and post-operative
condition in children with CLP except for /m/. A higher $F_3$ observed in the present study for children with CLP in the post-operative condition, could be due to the effect of lowering of the velum to produce sounds. Lowering of the velum allows nasal cavities to interact with oral cavity or increase the volume cavity, which could lead to a higher $F_3$. However, variations in the formants among children with CLP was observed in the previous studies by Casal et al., (2002); Deepthi, (2008); Navya and Pushpavathi, (2011); Vasanthi, (2001). This could be attributed to the methodological factors related to vowel environments studied in the respective studies.

Fifthly, yet another parameter i.e., bandwidths for the vowel /a/ were analyzed and the results revealed that $B_1$ and $B_2$ in the post-operative condition were found to be higher compared to the pre-operative condition in children with CLP. Results of the formant bandwidth analyzed across groups indicated a higher bandwidth in children with CLP compared to TDC. Higher bandwidth observed in children with CLP after surgical correction may be due to inadequate velopharyngeal closure during the production of speech sounds which could lead to an increase in the posterior vocal tract area of the tube that serves to increase the formant bandwidth. Another possibility for higher formant bandwidth in children with CLP who have adequate velopharyngeal closure could be due to the resonance that is perceived as hypernasal due to increasing in the trans-palatal transmission of the energy (Gildersleeve-Neumann & Dalston, 2001). The higher bandwidth in children with CLP could also be attributed to the muscular properties of the velum length, thickness, and scar of the operated palate. Findings of the present study are in agreement with the study by Deepthi (2008); Dickson (1962); Fant (1970); House and Stevens (1956) who reported of increased bandwidth of vowel formants for nasalized vowels. This may be due to the spread of low-frequency energy across the spectrum which could have lead to an increase in the formant bandwidths in children with CLP. Thus, the second hypothesis can be partially accepted, as a significant difference was found between TDC and CLP in the pre and post-operative conditions for all the parameters except for affrication duration. However, significant differences were observed only for few target consonants when compared across groups.

Sixth, observation of the present study is the results showed that there was no significant difference observed across gender for temporal and spectral parameters in
TDC and children with CLP across conditions. One of the reasons for the lack of difference across gender in temporal parameters may be due to the anatomical similarity of the vocal tract structures in typically developing children and children with CLP. Vocal tract development of normal children has been widely reported in the literature Aronson, (1990); Fant, (1966); Kaplan, (1960); Kent and Murray, (1982); Murray, (1978); Negus, (1949); Perry et al., (2001); Vorperian and Kent, (2007); Vorperian et al., (1999), (2005); Vorperian et al., (2009). The results of these studies indicated the similar vocal tract anatomy across the gender. A study by Fitch and Giedd (1999) indicated that there were no acoustic differences with respect to vocal tract length before 11 years of age between males and females.

Another study by Vorperian et al. (2009) indicated quantitative anatomical data on the development of the oral and pharyngeal part of the vocal tract from MRI imaging of individuals between birth to nineteen years in typically developing children. The oral portions of the vocal tract (VT) were segmented into different parameters such as lip-thickness (LTh), anterior cavity length (ACL), oropharyngeal width (OPhW), and VT- oral, and the pharyngeal (vertical) part of the VT into posterior cavity length (PCL) and nasopharyngeal length (NPhL). The study reported a significant difference in the growth trend for all the variables, which reflected on a general nonlinear growth development throughout the first to 18 years of life except for anterior cavity length. Their results also indicated that majority of the structures showed large difference across gender only after 12 years of age, while a large difference across gender was reported at an earlier age for only for NPhL and PCL. It was reported that even as the growth trend of some variables showed prepubertal differences across gender at particular age ranges, the significance of such differences appeared to be covered by the overall developmental rate differences between males and females. Further, the study indicated that the evaluation of growth curve type showed that most of the VT structures followed combination of both neural and somatic growth type except for LTh in females and OPhW in males. The growth curve with structures in the vertical plane (VT-V, PCL, ACL, and NPhL) indicated predominately on a somatic growth pattern.

The results of the present study support the findings by Fox and Nissen (2003); Munson, (2004). They reported a lack of difference on gender in frication
duration /s/ in typically developing children. However high degree of variability has
been reported in acoustic and physiologic studies in children’s speech (Eguchi &
Hirsh, 1969; Hillenbrand et al., 1995; Kent & Forner, 1980; Kent, 1976; Savithri,
1996; Sharkey & Fokin, 1985; Smith et al., 1995; Smith, 1978, 1992; Tingly &
Allen, 1975; Vorperian & Kent, 2007; Vorperian et al., 1999, 2005; Vorperian et al.,
2009). This variation could be attributed to the maturation of anatomical structures
and neuromotor control of the vocal organs as indicated in various other studies
reported in the literature.

Seventh, the results of the present study indicated significant difference across
the type of stimuli (voiced and unvoiced consonants) for all the temporal and spectral
parameters when voiced and unvoiced consonants were compared in TDC. Raphael
(1975) hypothesized that the difference in the type of stimuli may be due to the
duration of the vowel present between voiced and unvoiced consonants. To verify the
effect of vowel duration he studied the physiological control of durational 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. In this study by Raphael (1975), EMG activity peak associated
with vowel articulation occurred almost simultaneously in both the voiced and
unvoiced. He also found sustenance of muscular activity in the voiced consonants
relative to the voiceless consonants. To confirm the muscular activity he substantiated
with simultaneous acoustic recording. The acoustic recordings showed no durational
differences between the onset of consonant activity compared to the preceding vowel
which showed the durational difference between the vowels. He concluded that
voiced and unvoiced consonants were controlled physiologically by motor commands
to the muscles leading to the articulators, which are active in the formation of vowels.
He opined that the timing of these motor commands after the peak of the articulatory-
muscular activity is reached, the articulators maintain shape and positions that are
required for vowels somewhat longer when they precede voiced consonants. Results
of the present study support the findings of Gimson, (1962); House, (1961); Kenyon,
(1951); Locke and Heffner, (1940); Peterson and Lehiste, (1960); Raphael (1975).
They reported a significant difference in voiced and unvoiced consonants in the
typically developing children. In the present study, significant differences were not
observed among children with CLP across voiced and unvoiced consonants for all the
parameters. A possible reason could be that children with CLP are unable to build and maintain adequate intraoral breath pressure due to VPD during the production of voiced consonants as indicated in the present study.

Eight, the present study also aimed to study the perceptual parameters of speech in children with CLP in the pre and post-operative condition. The perceptual protocol by Henningsson et al., (2008) which is considered as a standard protocol was used to document the pre and post-operative speech parameter changes in children with CLP. Three parameters of speech-articulation, resonance and speech intelligibility were studied. In the present study, the first parameter considered for perceptual analyses was articulation. In articulation, occurrences of compensatory articulation were analyzed pre and post-operatively. The results of perceptual assessment indicated that articulatory errors were greater in the pre-operative condition in children with CLP. The presence of compensatory articulation was also observed in the post-operative condition. The results support the findings of Grunwell and Sell (2002) who reported that the presence of an articulatory error is due to abnormalities in the orofacial/nasal structures. In children with CLP, errors in speech production are observed due to the abnormalities in oronasal/facial structure/ function and growth, learned neuromotor patterns at the time of early infancy, and/or disturbed psychosocial development. Children with CLP exhibit varieties of speech sound errors in which, pressure consonants are most affected than the other sounds.

Bzoch (1970), Chapman (1991) and Russell (1991) reported a predominance of glottal and pharyngeal articulation observed in infants with a cleft during babbling stage. It can be observed from the literature that, phonological development in normal children is a gradual process which follows the normal stages of phonological development. However, in children with CLP phonological development is deviated to a certain extent and the acquisition of the phonology is also reported to be delayed compared to typically developing children (Harding & Grunwell, 1996; Kummer, 2008). Compensatory articulation is often observed in children with CLP even before surgery and may persist after surgery. Trost (1981) reported different types of compensatory articulation for pressure consonants. These compensatory articulations are reported to occur at glottal, laryngeal, pharyngeal and palatal level. Apart from these compensatory articulations, they have also reported of weak oral pressure consonants and other posterior productions. Speech sound production errors are
broadly classified into two types: Obligatory errors and optional or learned/compensatory errors (Trost-Cardamone, 1997). Obligatory errors are due to structural or neurogenic problems and require physical management. Optional or learned/compensatory errors that arise due to maladaptive articulatory placements learnt during the developmental periods. They exist despite an adequate velopharyngeal closure mechanism and require speech remediation. In the present study, both obligatory and learned/compensatory errors were observed in children with CLP.

The findings of the current study showed that among words, occurrences of the mid-dorsum palatal stops were found to be greater followed by, glottal stops (?) and pharyngeal stop/fricative/affricatives in the pre-operative condition. Results of the present study were in consonance with previous study by Gibboson and Hardcastle, (1989); Lawrence and Philips, (1975); Morley, (1970); Trost, (1981). They have reported compensatory articulation in the speech of children with cleft palate and reported that these children developed a habituated pattern during the course of their phonological development.

Occurrences of mid-dorsum palatal stops in the present study may be due to the increased contact and overuse of dorsum of the tongue in children with CLP. Mid-dorsum palatal stops are produced when middle and posterior part of the tongue contacts the posterior portion of the hard palate and anterior part of the soft palate to build-up an intraoral pressure to produce stop consonants. This error is often reported to be seen in an anterior oro-nasal fistula. These errors are noted, even without a palatal fistula after surgery (Trost, 1981). Michi et al., (1990) studied the abnormal production of articulation in children with CLP using lateral x-ray tracing method. They found that posterior portion of the tongue dorsum was elevated by making contact with the posterior portion of the hard palate and anterior part of the soft palate. This phenomenon was also referred to as lingual assistance (Trost, 1981). The high tongue body/posture helps in achieving the velopharyngeal closure for the high-pressure consonants.

There are many views on the development of abnormal tongue behavior. Yashmitha and Michi (1991) opined that high tongue position may be a routine behavior adopted at a very early age even before surgery of the palate in children with
CLP. Yamashita et al., (1992) reported 33% of palatal misarticulation in Japanese children with repaired CLP. Based on the EPG pattern she opined that children had retracted placement involving complete closure in the posterior region of the palate. Other compensatory errors reported in the present study are in support of the study by Sell and Grunwell (1990). They reported speech in children with unrepaired cleft over the age of 8 years in Sinhalese and found that the majority of the subjects produced glottal and pharyngeal articulation. This was attributed to the presence of cleft and habituated compensatory articulation behavior shown by the children with CLP.

In the post-operative condition, glottal stops (ʔ), mid-dorsum palatal stops and pharyngeal affricates/fricative were observed in the present study. However, the percentages of occurrences of compensatory articulatory errors were reduced in the post-operative condition compared to the pre-operative condition. Among errors due to nasalization, nasal fricatives were found to be higher followed by weak pressure consonants, substitution of nasal for oral consonants and nasalization of oral consonants. This finding was consistent with the previous reports in the literature Bozoch, (1971); Chapman, (1993); Grunwell and Russell, (1988); Harding and Grunwell, (1996); Harding and Grunwell (1998); McDonald and Baker, (1951); Morley, (1954) reported that active processes (articulatory errors) may continue even after a successful primary palatal repair. Even after the successful surgical correction, children with CLP often exhibit errors, which indicate a lack of velopharyngeal closure/ function (Van Demark et al., 1985). It is also observed that compensatory strategies are adopted by children before the surgery and they may continue to use the adopted behavior even after the surgical correction.

The findings of the present study indicate that even after surgery the articulatory errors were seen in children with CLP. Post-operative recordings in the present study were done after one month from the date of surgery and none of the children attended speech therapy. This may be also one of the reasons for persisting compensatory articulation in the present study in the post-operative condition. Reduced compensatory articulation was observed in the post-operative condition compared to the pre-operative condition. This may be due to tongue palate contact behavior in children with CLP, which could have changed after the surgical correction to some extent, which may lead to a reduction in the error pattern (Gibbon, 2004).
Another feature observed in the present study was weak oral pressure consonants. Weak oral pressure consonants could have occurred due to the reduction of intraoral pressure. Stengelhofen (1989) and McWilliams et al.,(1990) reported inadequate VP closure reduces supraglottal air pressure, which in turn affect the ability to build and maintain the intra-oral pressure because of the constant air escape through the nasal cavity. The presence of weak oral pressure consonants is reported widely in the literature (McWilliams et al., 1990; Henningsson & Isberg, 1990; Golding-Kushner, 2001; Henningsson, et al., 2008). Most often these consonants are not heard or perceived as omission due to lack of air pressure.

Van Hatum (1958) reported occurrence of nasal sounds for oral consonants and this error to be closely associated with the hypernasality. The occurrence of nasal fricative may be due to complete closure of tongue-palate constriction as reported by Gibbon (2004). She reported that with complete closure across the palate, the probability of central release of the air reduced, and the air escaped through lateral sides of the tongue producing lateral frication or through nose resulting in the nasal escape of air. The current result revealed improvement in the articulatory errors and errors due to nasalization across the conditions.

The second parameter considered in the perceptual assessment was resonance. Among the resonance parameters, hypernasality and nasal air emission were considered. Results of the present study showed hypernasality and nasal air emission were reduced in the post-operative condition compared to the pre-operative condition. Trost-Cardamone (1990b); Sell, (1992); Harding, (1993) reported that hypernasality, nasal air emission, and reduced intraoral pressure were expected consequences of the unoperated cleft palate during speech production.

Hypernasality is referred as excessive nasal resonance heard on vowel and sometimes observed on voiced consonants. Nasal air emission is referred as the audible escape of air through the nasal passage that accompanies or is coproduced with, high-pressure consonants (McWilliams et al., 1990). Nasal air emission and hypernasality are two different variables, even though they often coexist and are interrelated (D’Antonio & Scherer, 1995; Mc Williams et al., 1990; Witzel, 1995). In the present study, the overall degree of hypernasality reduced from moderate in the
pre-operative condition to mild in the post-operative condition. Results of the present study were in support of Chua et al., (2010); Murthy et al., (2010); Wu et al., (1990) who reported that on perceptual evaluation, hypernasal resonance was found to be reduced from moderate to mild in the post-operative condition in individuals with CLP. Perceived nasality in individuals with CLP in the post-operative condition, could be due to poor timing of velopharyngeal movements relative to the activity of other articulators and persistence of velopharyngeal dysfunction even after the surgical correction, which can lead to hypernasal speech (Dotevall et al., 2001; Jackson et al., 1980; Kuehn, 1976; Warren et al., 1985, 1993, 1994; Zimmerman et al., 1984).

The third parameter considered in the perceptual assessment was speech intelligibility. Speech intelligibility was assessed for speech understandability and speech acceptability. Speech understandability is explained as the degree to which the individual message can be understood by the listener and speech acceptability is explained as the degree to which speech calls attention to itself apart from the content of spoken message (Henningsson et al., 2008). The primary goal of any craniofacial team was to ensure that speech of children with CLP was understandable to the listener (Gunter et al., 1998; Khosla, Marby & Castiglione, 2008). For assessment of speech intelligibility, all the aspects of speech such as precise articulation, normal resonance, rate, and rhythm should be considered. Speech intelligibility depends on number of parameters such as speech sound errors, hypernasality, audible nasal air emission etc. Speech intelligibility is affected by the presence of hypernasality, audible air emission, lack of oral pressure and compensatory articulation as reported by Hutters and Henningsson (2004); Lohmander and Olsson (2004) and Whitehill (2002). The results of the present study showed that overall improvement in the mean rating scores of speech understandability and acceptability improved from moderate in the pre-operative condition to mild in the post-operative condition. In the present study, children with CLP exhibited hypernasality, nasal air emission, and compensatory articulatory error in the pre-operative condition, which can lead to reduced speech understandability and acceptability scores. However, in the post-operative condition, there was improvement observed in articulation and resonance, which was also reflected in the speech intelligibility.
In the post-operative condition, speech understandability and speech acceptability were reduced to mild from a moderate degree. This may be due to the surgical correction which mainly aims at the structural correction as reported by Karnell (2011). In the present study primary palatal surgeries, such as Two-flap palatoplasty and Furlow’s Double Opposing Z plasty are performed. These surgical corrections aim to reduce the hypernasality and nasal air emission. However, the presence of VPD is reported in some children (Gunther et al., 1998). Like indicated in previous sections, palatal surgeries are sometimes reported to leave scars and tighten and thickness of soft palate muscles and tissue thus affecting the mobility of the velum (Van Lierde et al. (2002); Mora et al., (2007 & 2009) which leads to VPD in most of the children after primary palatal surgery. However, the findings of the present study indicated improvement after surgical correction in speech understandability and speech acceptability. The results of the present study related to speech understandability are in support of a study by Gnanavel (2015). He found that there was a significant improvement in speech understandability before and after the correction of velopharyngeal dysfunction.

In the recent past, there have been a number of studies, which have focused on different speech situations (words, sentences, conversational/connected speech) to evaluate the speech (LeBlanc & Shprintzen, 1996) to provide a balanced sample. Howard and Lohmander (2011) reported that conversational/connected speech was more complex and represents the everyday speech. Hutters and Hennigsson, (2004); Lohmander et al., (2005); Peterson-Falzone et al., (2006); Watson et al., (2001) have suggested various speech stimuli samples. Perceptual assessment of the present study showed no differences across the stimuli. A result related to the type of speech stimuli in the present study was in support of findings of Gnanavel and Pushpavathi (2012) and Masterson et al., (2005). They did not find any difference on articulation and intelligibility across words and sentences. These findings were contradicting with the previous studies of Hodge and Gotzke, (2007); Johnson et al., (2004); Shriberg and Lof, (1991). Their studies reported a good correlation and intra and inter-agreement in conversational speech than sentence repetitions and word naming. The difference seen in the current study could be due to the methodological variations related to the speech sample used in the present study. Whitehall (2002) reported that rating scale procedures can be verified based on the results of reliability and validity. Reliability
of the rating procedure in the present study was found to be higher. The inter-judge and intra-reliability for the judges were high for across the stimuli.

Thus, the third hypothesis can be partially accepted as a significant difference was found between the pre and post-operative conditions in children with CLP for variables such as hypernasality and speech intelligibility. On the other hand, there was no significant difference found between the pre and post-operative conditions in children with CLP for articulation in terms of compensatory articulation and errors due to nasalization.

It can be observed from the present study that, children with CLP showed improvement in some of the temporal and spectral parameters after the surgical correction. However, not all the parameters indicated improvement after the surgical correction. The findings of the study thus indicated that surgical correction alone may not be successful in speech correction. In addition to surgical correction, speech therapy is likely to be important in modifying the active processes in cleft-types (Harding & Grunwell, 1998). The perceptual evaluation in the present study indicated that speech parameters such as articulation, resonance, and speech intelligibility were affected in the pre-operative condition and the same were assessed in the post-operative condition. After the surgical intervention, some of the speech characteristics such as articulatory errors, resonatory characteristics were improved. However, few articulatory errors were present even after the surgical correction. This calls for the attention of Speech-Language Pathologists to provide speech therapy and recommend appropriate therapy techniques for speech correction. Early intervention for these children will help to modify active cleft-type processes.