An Acoustic Analysis of Hypernasality in the Speech Production of Iraqi Children with CLP/VPI

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Abstract:

The study aims at analysing hypernasality in the speech production of Iraqi Arabic-speaking children with surgically treated cleft lip and palate, with special focus on acoustic properties. It attempts first to display the acoustic properties of the speech production over the three stages: pre-surgery, post-surgery, and post-therapy, and then explain improvement occurs after the surgery or therapeutic sessions. The present study is the first in Iraq dealing with the speech production of persons with cleft lip and palate (CLP) and velopharyngeal insufficiency (VPI). investigates how (CLP) and (VPI), which are congenital conditions, can significantly affect speech production, resulting in articulatory or phonatory disorders. For accurate assessment and diagnosis of spectral anomalies associated with these disorders, that are crucial for guiding intervention strategies and improving communication outcomes, the programme MATLAB is used. This software serves as a powerful tool for analyzing spectral features, facilitating the identification of abnormalities related to CLP and VPI. The study has arrived at some important findings. In the case of UCLP, ICP, and BCLP, the role of both surgical interventions and therapeutic sessions is clearly stated in the study.

Keywords: (hypernasality, speech disorder, CLP, VPI ،CSCs, MATLAB.)

1. Introduction

Hypernasality is a speech disorder characterized by improper closure of the palate and pharynx tissues, leading to a nasal sound in vowels. This condition can commonly be seen in individuals with clefts palates or after velum resection, due to velopharyngeal insufficiency (dysfunction) (Paal, 2005 and Lewis et al., 1993). Assessing the extent of this condition quantitatively is crucial for deciding on the right speech therapy or determining the need for surgery. Various methods, including nasometry, fiberscopy, aerodynamic tests, electromyography, and hypernasality assessment, are employed to examine velopharyngeal function. However, none of these methods alone can offer a completely objective evaluation (Pegoraro et al., 2008; Brunner et al., 2005; Golding, 1990), and such evaluations can be challenging for patients. Since hypernasality assessments often rely on subjective judgments by experienced listeners, whose standards may vary, they lack objectivity. The present study aims to analyse the acoustic features of the speech of those affected by hypernasality from cleft lip and palate (CLP) and/or velopharyngeal insufficiency (VPI), to facilitate more objective evaluations.

2. Normal Resonance: Definition

Resonance refers to the quality of voice that emerges from the vibration of the sound within the pharynx, oral cavity, and the nasal cavity(Kummer and Lee,1996; Stelck, et al. 2011; Prathanee, et al. 2013). This process involves the vocal tract filtering these sounds, thus selectively amplifying certain harmonics based on the tract's dimensions and shape. The quality of speech and voice hinges on the equilibrium of sound vibrations across these regions, which is maintained when the velum elevates to touch the pharynx's rear wall, facilitating velopharyngeal closure. This action is crucial for generating air pressure and sound in the mouth for articulating various speech sounds. The velopharyngeal (VP) valve plays a pivotal role in determining speech resonance, along with other factors such as the size and shape of resonating cavities, tongue position, and the mouth's openness. The modulation of these aspects affects the vocal tract's dimensions and shape, thereby influencing resonance quality. Normal resonance achieves a balance between oral and nasal sound energies, differing across vowels, consonants, and languages (Peterson-Falzone, Hardin-Jones, & Karnell, 2010).

3. Resonance Disorders: Definitions and Varieties

Resonance disorders arise from disruptions in air flow due to openings, inconsistent movements, or blockages, classified into hypernasality, hyponasality, and cul-de-sac resonance. Hypernasality occurs with excessive nasal cavity resonance during speech, often sounding nasally. This can lead to nasal air emission and weakened consonants (Makarabhirom,2023; Kummer, 2008; Lohmander and Olsson, 2004) This type makes the patient sound as if he/she is speaking through the nose. In severe hypernasality, other abnormal speech characteristics can occur. For instance, nasal air emission (air that escapes out of the nose) can be heard in the production of specific consonants (such as /p/, /t/, /k/, /s/, /sh/, and/ch/). When there is nasal emission, the consonants become weak or they can be omitted. Moreover, the child might use abnormal speech sounds (like a hard (uh) instead of the consonant sound /g/) because of the lack of air pressure in the mouth.

Hypernasality is attributed to an abnormal opening between the mouth and nose during speech. This is normally due to a form of velopharyngeal dysfunction (velopharyngeal insufficiency or velopharyngeal incompetence). Common causes include a history of cleft palate or submucous cleft palate. Hypernasality can occur after adenoidectomy in some cases. A few neurological problems might lead to poor movement of the velopharyngeal structures, resulting in hypernasality.

Hyponasality manifests with insufficient nasal resonance, producing a congested sound, typically caused by blockages where enlarged tonsils or adenoids are often the cause**.** Cul-de-sac resonance, on the other hand, results from trapped sound in the throat or nose, rendering the speech muffled. These conditions stem from velopharyngeal dysfunction, with cleft palate being a primary cause.

Hypernasality, in particular, can occur with other types of abnormal speech characteristics: nasal air emission, weak consonants, and abnormal articulation (Kummer et al, 2015; Oren et al, 2020).

4. *Velopharyngeal Dysfunction (VPD)*

VPD indicates inconsistent or incomplete closure of the velopharyngeal valve during oral sound production, encompassing velopharyngeal insufficiency (VPI), incompetence, and mislearning. These issues can lead to speech resonance disorders, with a significant number of cleft palate surgery patients experiencing VPI(Woo, 2012; Marsh,2003; Kummer and Baylis, 2009).

5. *Cleft Lip and Palate Overview*

Cleft palate is the condition most commonly associated with VPD (Kummer, Marshall, & Wilson, 2015). Overall, up to 30% of the individuals who have undergone cleft palate repair experience continued to have a velopharyngeal insufficiency (Ha, Koh, Moon, Jung, & Oh, 2015; Phua & de Chalain, 2008; Witt, Wahlen, Marsh, Grames, & Pilgram, 1998; Zhao et al., 2012).

A cleft is an abnormal opening or fissure in a body part or organ. According to Stedman’s Medical Dictionary, 25th edition, clefts of the lip and palate are congenital anomalies that result from incomplete merging or fusion of embryologic processes normally uniting in the formation of the face (Spraycar, 1995). Embryologic merging of the upper lip occurs roughly between the 5th and 7th weeks of gestation, while fusion of the palatal shelves occurs roughly between the 8th and 10th weeks (Burdi, 2006; Burdi & Faist, 1967). A cleft might happen when these embryologic processes are interrupted. Clefts may occur due to internal (e.g., genetic, intrauterine) and external (e.g., teratogenic) events. A cleft palate may influence the entire palate or part of it. The cleft in the palate causes a space which connects the oral cavity with the nasal cavity. Clefts are various in their length and width. In comparison with cleft palate, cleft lips are of more negative visual impact. Cleft lips, which can be harder to diagnose, may cause serious difficulties in swallowing and speech development. (Watson, 2001).

Cleft lip and palate (CL/P) are congenital anomalies occurring due to incomplete fusion during facial development, with their prevalence varying across demographics, genders, and types (Bender, 2000). The frequency of CL/P globally is approximately 1 in 700, with disparities among ethnic groups, genders, and socio-economic backgrounds(Bernheim et al., 2006; Mossey et al., 2009). For example, Souza and Raskin (2013) reported that the highest prevalence is observed among descendants of Asian or Native North American populations, intermediate among the Caucasians and the lowest among Africans. In terms of cleft type, Kianifar et al (2015) noted that a combination of cleft lip and cleft palate is more common than an isolated occurrence of either.

Mossey and Modell (2012) reported that Northern Europeans, Asians, Native Americans, and Aboriginal Australians are more commonly affected by unilateral or bilateral cleft lip and palate. On the contrary, among Africans and those of African ancestry, cleft lip is more prevalent (Mossey and Little, 2002). Such variations may happen because of the congenital variety in the gene pool of a specific race (Westreich, 2000). In terms of gender, cleft lip and cleft lip with a cleft palate are more prevalent in men than in women, while isolated cleft palate is seen more in women than in men (Meng et al., 2006; Jagomagiet al., 2010).

CLP is one of the most frequent birth malformations, which may also occur in association with other congenital anomalies such as clubfoot, Pierre Robin Syndrome, Spina bifida, and as part of an identified syndrome, in which case the clefting is often referred to as syndromic. A cleft occurring in isolation (i.e., not as part of a syndrome) is generally referred to as non-syndromic. Various occurrence rates of CLP with associated anomalies have been reported. Shprintzen et al. (1985) reported that 40% of all cleft infants have associated anomalies. Some estimates (e.g., Christensen, 1999) lower this Figure to 25% or less, while others (e.g., Tolarova and Cervenka, 1998; Forrester and Merz, 2004) raise it up to as much as 70%.

6. The Experiment

Before indulging into the results and findings, it is useful to provide some related information about the sample of the study, methodology, and the programme used.

6.1 The Sample of the Study

Speech samples were obtained from10 unpaid children aged between 5 and 11 years, with a repaired cleft lip, and a control group of typically-developing children that additionally recruited specially for the acoustic analysis part of the Pilot Study II. The control group in this study consists of six unpaid children: Um-Albaneen (10 years old), Batool (7 years old), Zainab (5 years old), Ali (7 years old), Laith (11 years old), and Mahdi (6 years old). The selection of individuals for the control group was based on the criterion of not having any speech abnormalities or facial deformities. The control group functions as a benchmark for the typical speech production features in which their acoustic measurements serve as a reference point for assessing and evaluating any enhancements in speech output among participants CLP/VPI. Acoustic readings provide unbiased assessments of speech properties. This study intends to quantitatively evaluate and compare the speech production outcomes of CLP/VPI participants before and after interventions,and post therapy stage, utilising the readings from the control group.

6.2 Methodology of the Study

A List of 174 Iraqi Arabic words is used in this study. The list mainly contains mono-syllabic words for the elicitation and repetition respectively of the consonants of Iraqi Arabic in different positions. First, the speech production of these words by the control group is recorded and analysed using MATLAB to be used as a reference scale against which the readings obtained from the patients are evaluated to create a standard level of typical speech output. This acoustic analysis is done over the three stages: pre-surgery, post-surgery, and post-therapy. The acoustic data obtained from the control group are a baseline for the methodological considerations:

1- Evaluation of Improvement: before and after the surgery intervention, and therapeutic sessions, the acoustic characteristics of participants with CLP/VPI are compared to the baseline of the control group to evaluate if there are statistically significant improvements in speech output.
2- Statistical analyses, such as RCD, is employed to evaluate the average variations in acoustic data between the control group and the children with CLP/ VPI, both before and after the intervention and post therapy stage.

6.3 The Sound Analysis Programme of MATLAB

Through a sound analysis programme of MATLAB, various acoustic plots will be obtained. These plots, sound images, include oscillogram, spectrogram, spectrum, cepstrogram, histogram, and correlogram. They additionally explain and describe the case of each patient at the three different stages: pre-surgery, post-surgery, and post-therapy.

Next, these images or plots, via the same programme, are converted into acoustic readings. They are transferred into eight readings, which are sound prints. These readings are: crest factor, autocorrelation, Max value, Min value, Mean value, RMS, dynamic range, and single duration. After that, these readings are converted into statistical tables through an experimental design for analysis, which is Completely Randomized Design (CRD)[1].

6.4 Results and Discussion

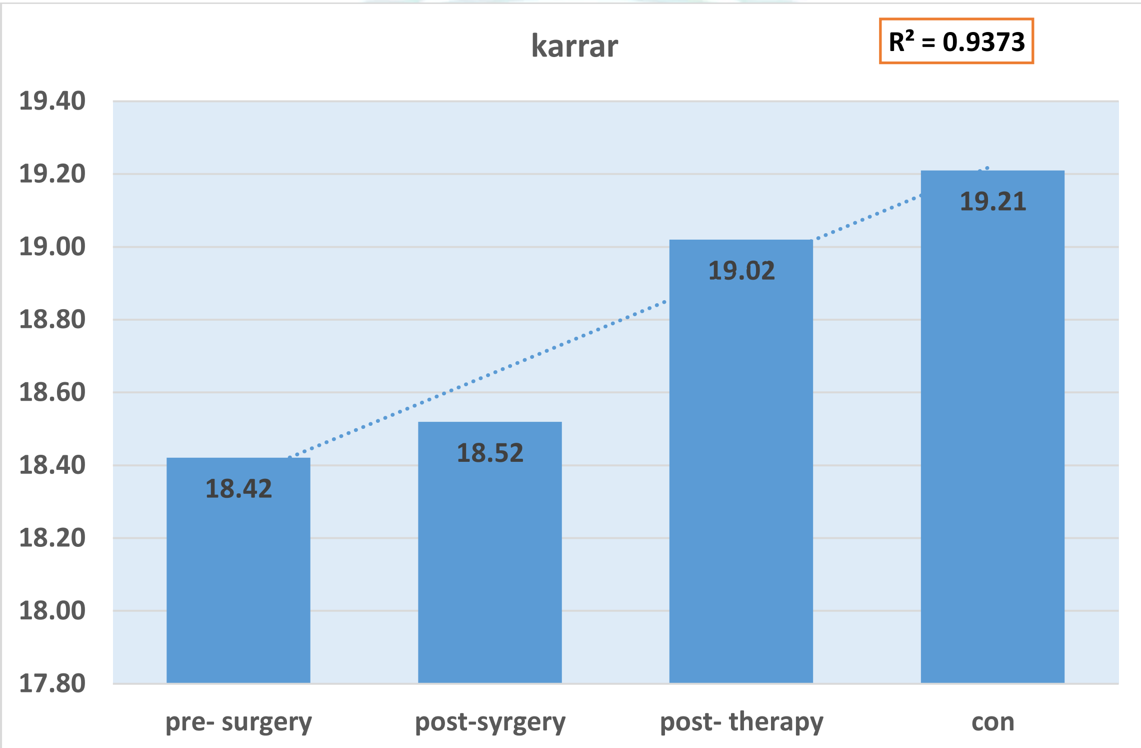
In this part of the study, each case of the patients will be discussed in detail.

6.4.1 Karrar

The following chart is a result of converting the above acoustic readings into a statistical representation. The chart reveals all the CSCs over the different stages. It shows the results of the three stages in comparison with the control group. It indicates that there are noteworthy differences at ($P<0.01$), as the control group and post-therapy designate an apparent change when compared to the pre-surgery and post-surgery results. However, the control group (19.21) does not differ from the post-therapy (19.02) at LSD (0.242), which clarifies that the patient has improved the CSCs, as stressed by R^2 and the improvement percentage (93.73%).

[1] Samples of acoustic images and readings are given in the appendix.

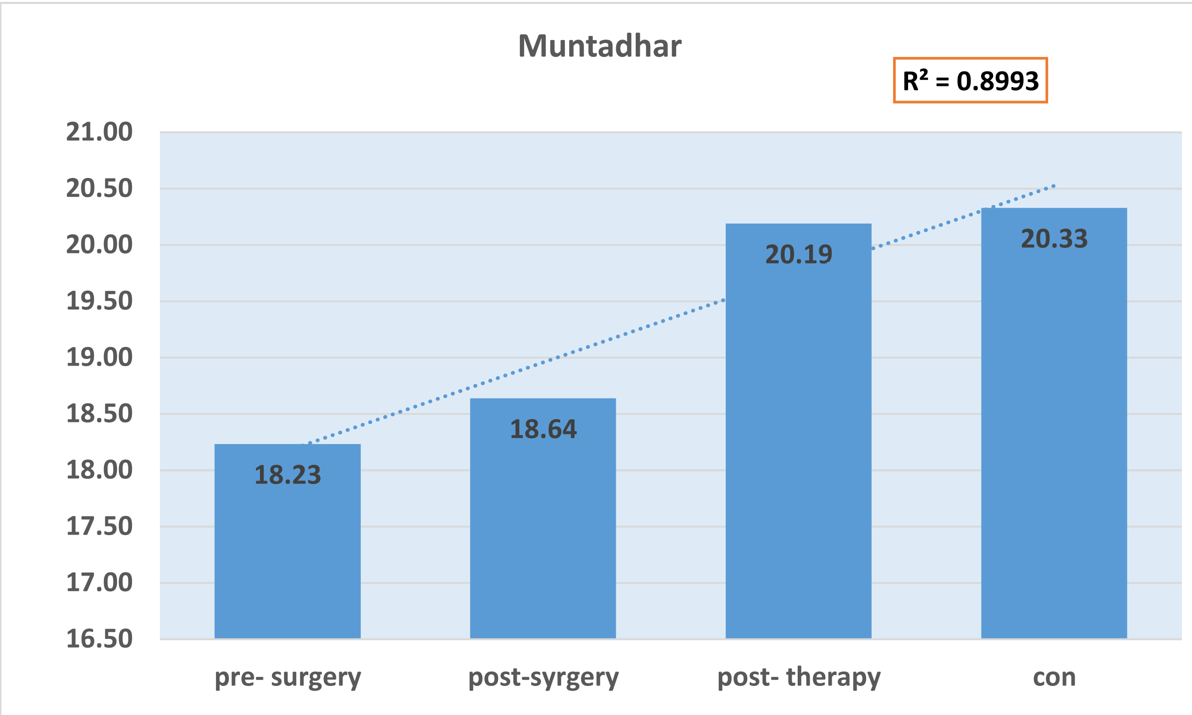
Figure 1: Karrar's Acoustic Readings Chart



6.4.2 Muntadhar

In addition, these readings are given in the form of a chart below (Figure 2), through CRD. The chart offers the CSCs of Muntadhar at the pre-surgery stage, post-surgery stage, and post-therapy stage in comparison with the control group. It reveals valuable differences at (P<0.01), as the control group and post-therapy show an obvious change when compared to the pre-surgery and post-surgery results. However, the control group (20.33) does not differ from the post-therapy (20.19) at LSD (0.17), which clarifies that the patient has improved the CSCs, as stressed by R^2 and the improvement percentage (89.93%).

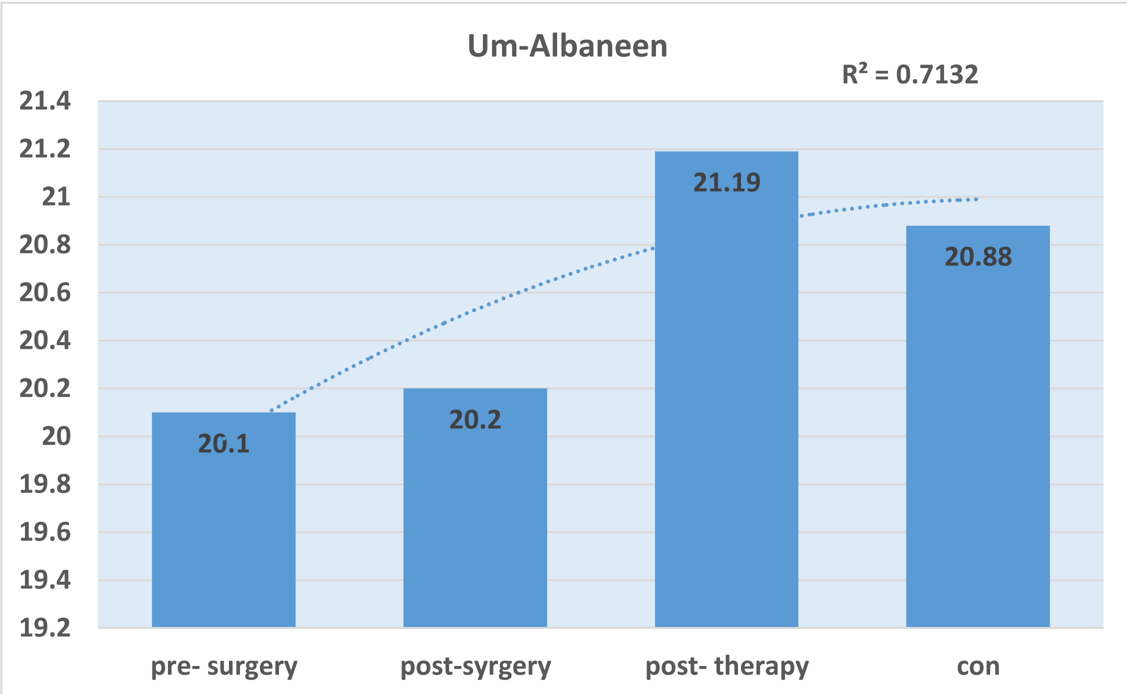
Figure 2: Muntadhar's Acoustic Readings Chart



6.4.3 Um Albaneen

The chart below introduces the CSCs of Um-Albaneen at the three stages, pre-surgery, post-surgery, and post-therapy, in comparison with the control group. It indicates that there are no significant differences between the pre-surgery stage and post-surgery stage on the one hand and the control group on the other. However, it affirms that the post-therapy (21.19) significantly differs from the pre-surgery, post-surgery and the control group at LSD (0.072). As stressed by R^2 , the improvement percentage (71.32%).

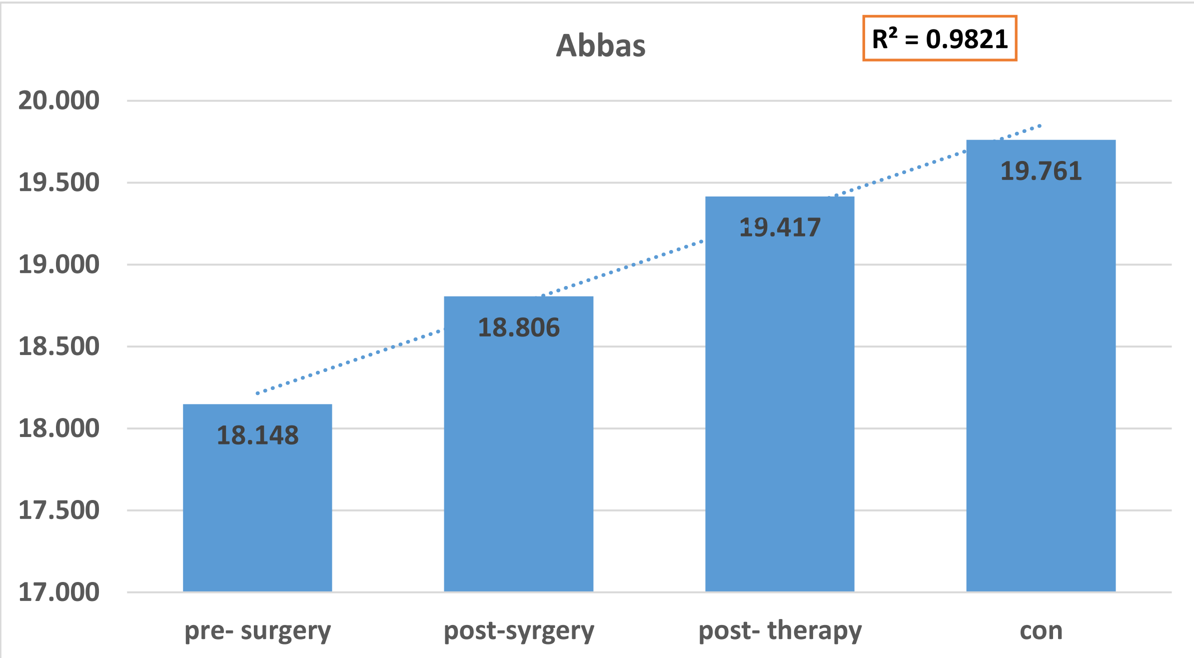
Figure 3: Um Albaneen's Acoustic Readings Chart



6.4.4 Abbas

The next chart, which concerns the case of the patient Abbas, presents all the CSCs at the pre-surgery stage, post-surgery stage, and post-therapy stage in comparison with the control group. It shows that there are significant differences at ($P<0.01$), as both the control group and post-therapy indicate a noticeable change when compared to the pre-surgery and post-surgery results. However, the control group (19.761) does not differ from the post-therapy (19.417), which is not significant at LSD=0.42. The patient has improved the CSCs, as stressed by R^2 and the improvement percentage (98.21%).

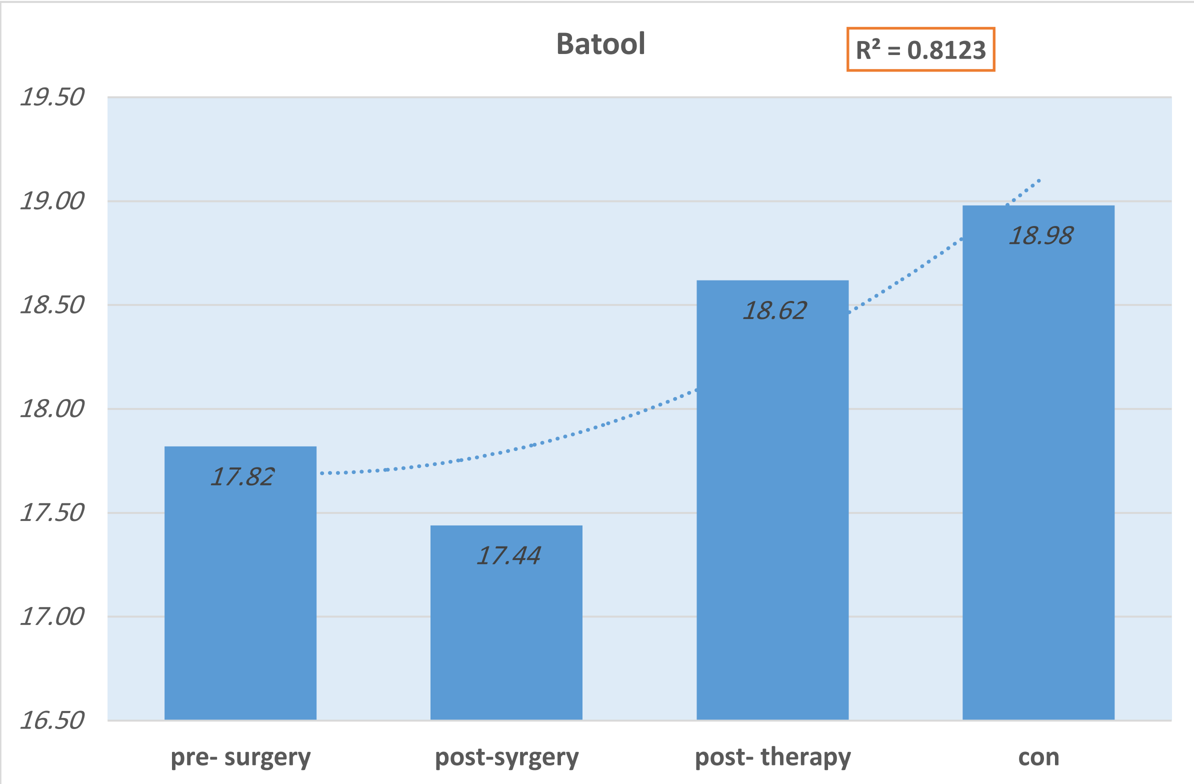
Figure 4: Abbas's Acoustic Readings Chart



6.4.5 Batool

The statistical analysis of Batool's case can be found in the following chart (Figure 5), which displays all the CSCs at the pre-surgery stage, post-surgery stage, and post-therapy stage in comparison with the control group. It shows that there are significant differences at ($P<0.01$), as both the control group and post-therapy indicate a clear change when compared to the pre-surgery and post-surgery results. Nevertheless, at LSD (0.39), the control group (18.98) does not differ from the post-therapy (18.62), which clarifies that the patient has improved the CSCs, as stressed by R^2 and the improvement percentage (81.23%).

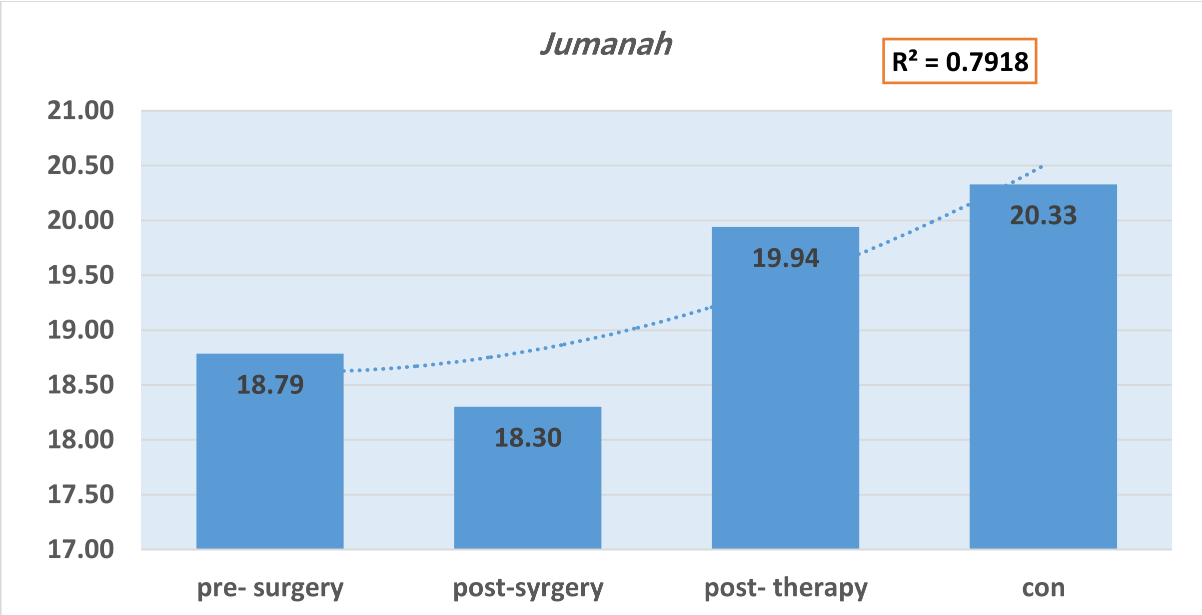
Figure 5: Batool's Acoustic Readings Chart



6.4.6 Jumanah

The chart below displays the results of analyzing the speech disorder cases as produced by Jumanah. It shows the results of the three stages in comparison with the control group. It indicates that there are noteworthy differences at (P<0.01), as the control group and post-therapy designate an apparent change when compared to the pre-surgery and post-surgery results. However, the control group (20.33) does not differ from the post-therapy (19.94) at LSD (0.47), which clarifies that the patient has improved the CSCs, as stressed by R^2 and the improvement percentage (79.18%).

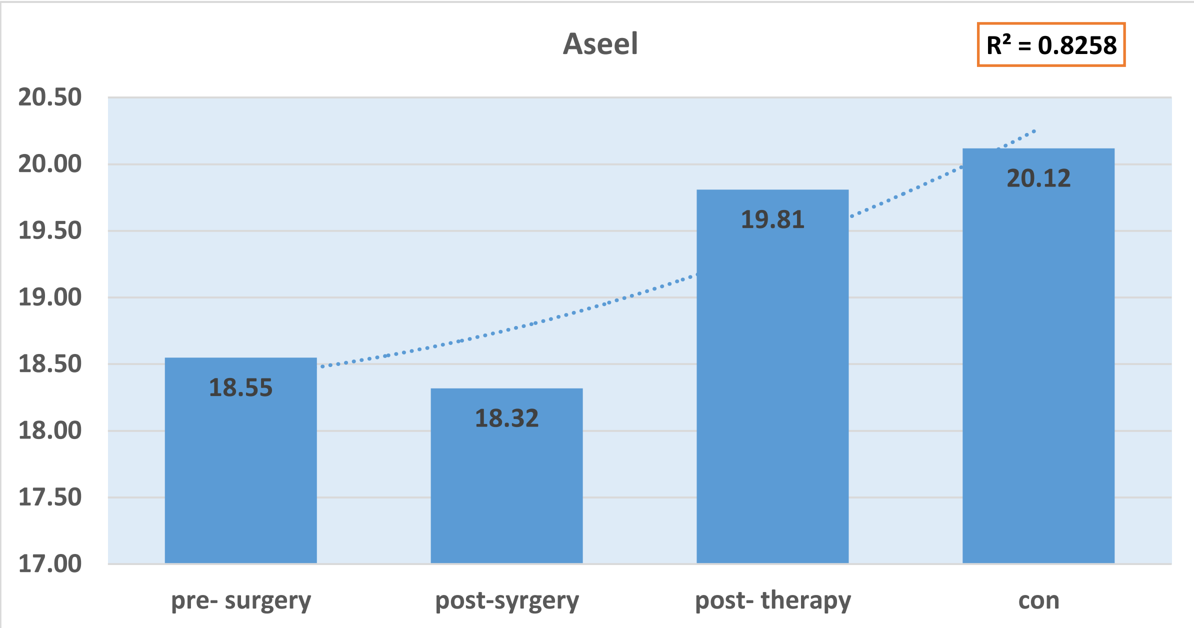
Figure 6: Jumanah's Acoustic Readings Chart



6.4.7 Aseel

The following chart presents the cleft speech characteristics of Aseel, at the different stages in comparison with the control group. It indicates that there are significant differences at ($P<0.01$), as both the control group and post-therapy indicate a noticeable change when compared to the pre-surgery and post-surgery results. In addition, at LSD (0.44), there is also a momentous difference between the control group (20.12) and the post-therapy stage (19.81). The improvement percentage in the case of Aseel is found to be (82.58 %) as stressed by R^2.

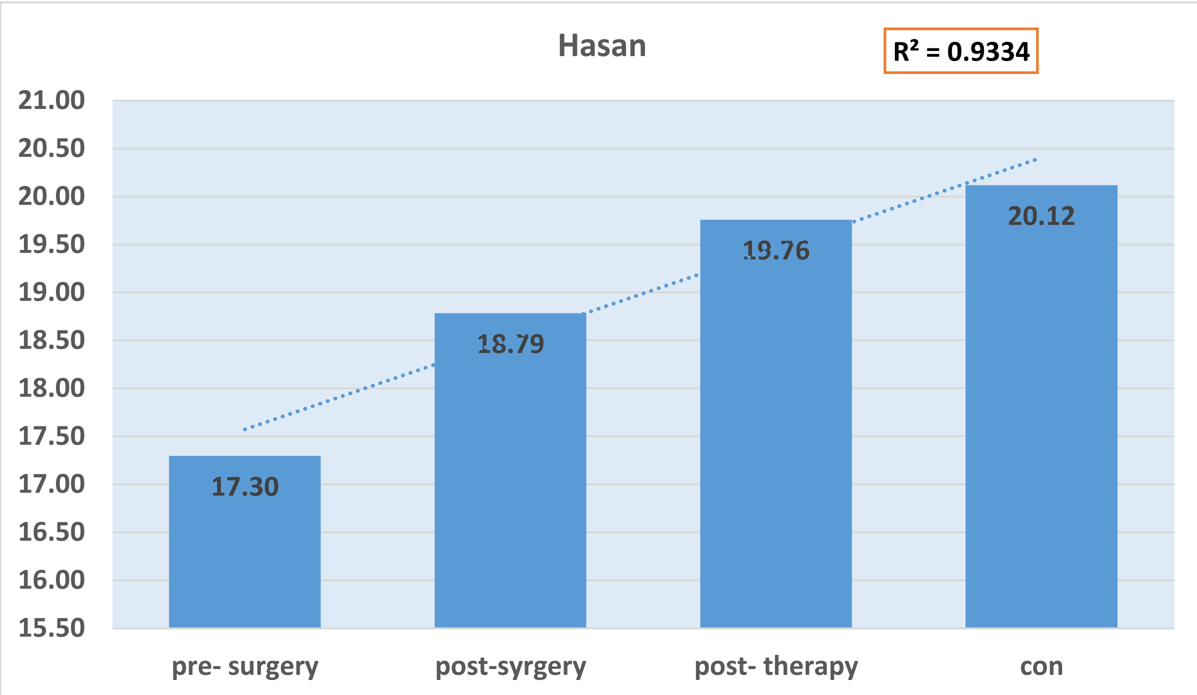
Figure 7: Aseel's Acoustic Readings Chart



6.4.8 Hasan

The chart gives the speech disorder cases of the patient Hasan at the three various stages, pre-surgery, post-surgery, and post-therapy, in comparison with the control group. It demonstrates that there are significant differences at (P<0.01), where both the control group and post-therapy indicate an obvious change when compared to the pre-surgery and post-surgery results. Nevertheless, the control group (20.12) does not greatly differ from the post-therapy (19.76) at LSD (0.42), which clarifies that the patient has improved the CSCs, as stressed by R^2 and the improvement percentage (93.34%).

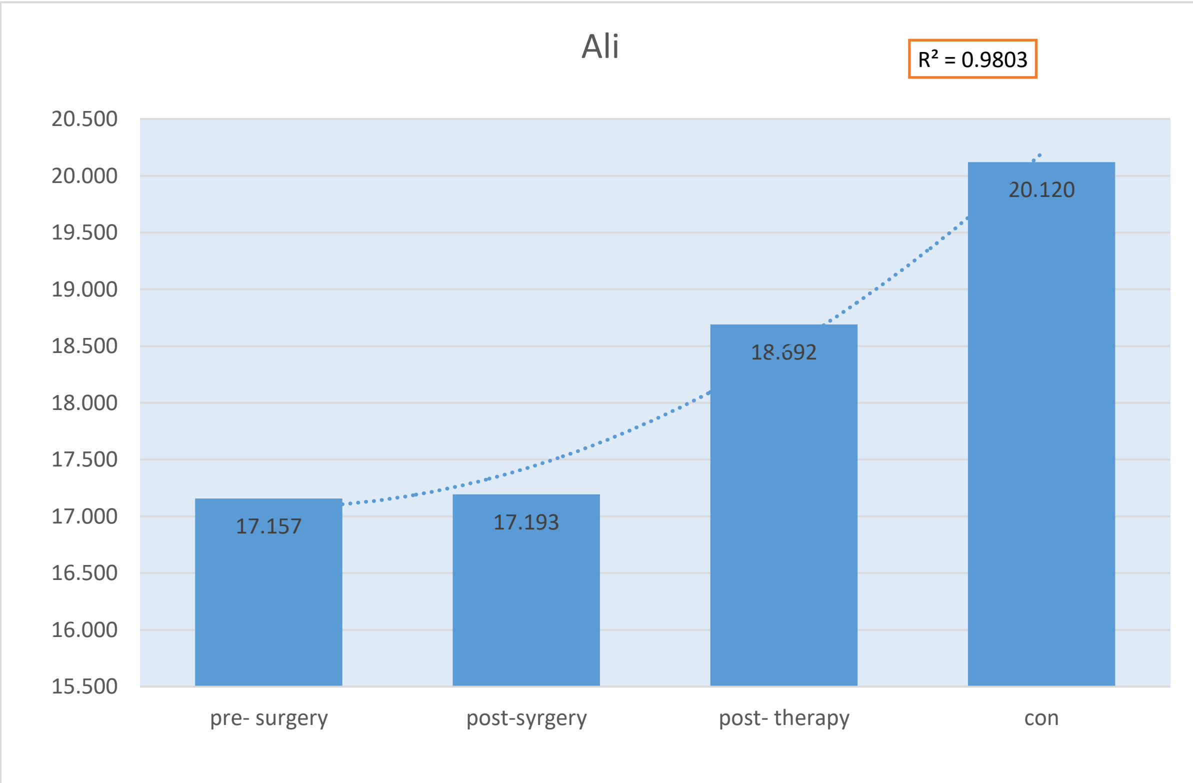
Figure 8: Hasan's Acoustic Readings Chart



6.4.9 Ali

The next chart displays the results of another patient, Ali. It provides the CSCs that are recorded at each of the three stages: pre-surgery stage, post-surgery stage, and post-therapy stage. As can be seen in the chart, there are significant differences at (P<0.01). When the control group and post-therapy are compared to the pre-surgery and post-surgery, they show an obvious change. Thus, the number of speech disorder cases decreases. At LSD (0.058) It is also found that the control group (20.120) significantly differs from the post-therapy (18.692). The patient here scores an improvement percentage of (98.03%).

Figure 9: Ali's Acoustic Readings Chart



6.4.10 Yousif

The chart below provides the results of the analysis of all the CSCs in the case of Yousif at the three stages of pre-surgery, post-surgery, and post-therapy in comparison with the control group. It reveals significant differences at ($P<0.01$), as the control group and post-therapy show an obvious change when compared to the pre-surgery and post-surgery results. In addition, it discloses a delicate difference between the control group (20.33) and the post-therapy stage (19.89) at LSD (0.461). The improvement percentage as stressed by R^2 is (87.74%).

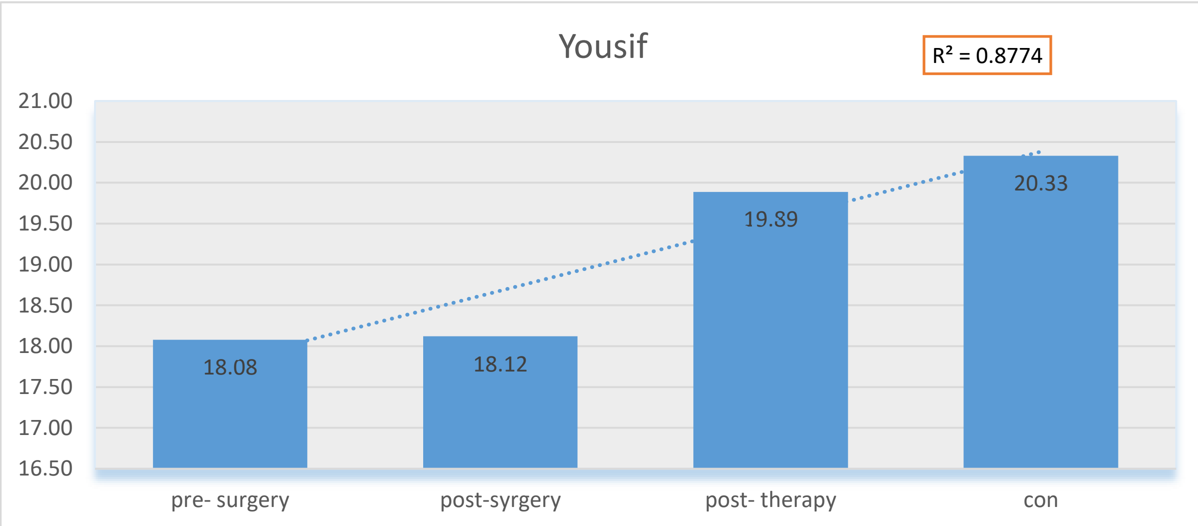


Figure 10: Yousif 's Acoustic Readings Chart

7. Conclusions

Having carried out the analysis of the results, the researchers have arrived at some concrete conclusions:

1. Generally speaking, patients with cleft lip/palate have shown many speech disorder cases in the production of the words selected for the study.

2. The therapeutic sessions prove to be useful in the improvement of the cleft speech characteristics in the speech production of the patients.

3. The acoustic analysis of the speech production of the patients, based on the cleft type they have, shows various aspects. First, it is revealed that, in the case of UCLP, the difference between the pre-surgery stage and post-surgery stage is insignificant, which indicates that the improvement degree is delicate. However, the difference between the post-therapy stage and post-surgery stage is significant, where a valuable improvement degree is found. In comparison with the control group, the acoustic analysis stresses that the post-therapy stage has no significant difference.
4. In the case of the patients having ICP cleft type, the acoustic analysis discloses that the difference between the post-therapy stage and the control group is significant, which

confirms that there is a valuable improvement in the speech disorder cases of the patients.

5. In addition, it is acoustically found that, in the case of BCLP, there is an insignificant difference between the pre-surgery stage and the post-surgery stage, which stresses that the improvement is delicate. However, the significant difference between the post-surgery stage and post therapy stage affirms the valuable improvement. And this is stressed by the fact that the results in the post-therapy stage are close to the control group.

References

Bernheim, N., Georges, M., Malevez, C., De Mey, A., & Mansbach, A. (2006). Embryology and epidemiology of cleft lip and palate. B-ENT, 11–19.

Burdi, A.R., & Faist, K. (1967). Morphogenesis of the palate in normal human embryos with special emphasis on the mechanisms involved. American Journal of Anatomy, 120, 149-159.

Burdi, Alphonse. (2006). Cleft Lip and Palate. 10.1007/3-540-30020-1_1.

Christensen K. (1999). The 20th century Danish facial cleft population--epidemiological and genetic-epidemiological studies. The Cleft palate-craniofacial journal : official publication of the American Cleft Palate-Craniofacial Association, 36(2), 96–104. https://doi.org/10.1597/1545-1569_1999_036_0096_tcdfcp_2.3.co_2.

Forrester, M. B., & Merz, R. D. (2004). Descriptive epidemiology of oral clefts in a multiethnic population, Hawaii, 1986-2000. The Cleft palate-craniofacial journal : official publication of the American Cleft Palate-Craniofacial Association, 41(6), 622–628. https://doi.org/10.1597/03-089.1

Ha, S., Koh, K. S., Moon, H., Jung, S., & Oh, T. S. (2015). Clinical Outcomes of Primary Palatal Surgery in Children with Nonsyndromic Cleft Palate with and without Lip. *BioMed research international*, 2015, 185459. https://doi.org/10.1155/2015/185459

Jagomägi, Triin & Soots, Marianne & Saag, Mare. (2010). Epidemiologic factors causing cleft lip and palate and their regularities of occurrence in Estonia. Stomatologija / issued by public institution "Odontologijos studija" ... [et al.]. 12. 105-8.

Kianifar, H., Hasanzadeh, N., Jahanbin, A., Ezzati, A., & Kianifar, H. (2015). Cleft lip and Palate: A 30-year Epidemiologic Study in North-East of Iran. Iranian journal of otorhinolaryngology, 27(78), 35–41.

Kummer , A. W. and Linda Lee. (1996). Evaluation and Treatment of Resonance Disorders Article in *Language Speech and Hearing Services in Schools*.

Kummer, A. W., & Baylis, A. L. (2009). Assessment of velopharyngeal function. *Comprehensive cleft care*, 589-605.

Kummer, A., Marshall, J., & Wilson, M. (2015). Non-Cleft Causes of Velopharyngeal Dysfunction: Implications for Treatment. *International Journal of Pediatric Otorhinolaryngology*, Volume 79, Issue 3, pp. 286-295.

Kummer, Ann. (2008). Resonance disorders and velopharyngeal dysfunction (VPD). *Cleft palate and craniofacial anomalies*. 176-213.

Lohmander, A., & Olsson, M. (2004). Methodology for perceptual assessment of speech in patients with cleft palate: a critical review of the literature. *The Cleft palate-craniofacial journal : official publication of the American Cleft Palate-Craniofacial Association*, *41*(1), 64–70. https://doi.org/10.1597/02-136

Makarabhirom, K., Prathanee, B., & Rattanapitak, A. (2023). Myanmar Articulation, Resonation, Nasal Emission, and Nasal Turbulence Test: A Preliminary Study. *Archives of plastic surgery*, *50*(5), 468–477. https://doi.org/10.1055/s-0043-1771522

Marsh J. L. (2003). Management of velopharyngeal dysfunction: differential diagnosis for differential management. *The Journal of craniofacial surgery*, *14*(5), 621–629. https://doi.org/10.1097/00001665-200309000-00004

Meng T, Shi B, Zheng Q, et al. (2006). Clinical and epidemiologic studies of nonsyndromic cleft lip and palate in China: Analysis of 4268 cases. Ann Plast Surg, 57(3): 264–9.

Mossey, P. A., & Modell, B. (2012). Epidemiology of oral clefts 2012: an international perspective. Frontiers of oral biology, 16, 1–18. https://doi.org/10.1159/000337464.

Mossey, P. A., Little, J., Munger, R. G., Dixon, M. J., & Shaw, W. C. (2009). Cleft lip and palate. The Lancet, 374(9703), 1773-1785.

Oren, Liran et al. (2020). “Understanding Nasal Emission During Speech Production: A Review of Types, Terminology, and Causality.” *The Cleft palate-craniofacial journal* : vol. 57,1 (2020): 123-126. doi:10.1177/1055665619858873)

Peterson-Falzone, Sally & Hardin-Jones, Mary & karnell, Michael. (2010). Cleft Palate Speech. Mosby/Elsevier.

Phua, Yun & de Chalain, Tristan. (2008). Incidence of Oronasal Fistulae and Velopharyngeal Insufficiency After Cleft Palate Repair: An Audit of 211 Children Born Between 1990 and 2004. The Cleft palate-craniofacial journal: official publication of the American Cleft Palate-Craniofacial Association. 45. 172-8. 10.1597/06-205.1.

Prathanee, B., Thanawirattananit, P., & Thanaviratananich, S. (2013). Speech, language, voice, resonance and hearing disorders in patients with cleft lip and palate. *Journal of the Medical Association of Thailand = Chotmaihet thangphaet*, *96 Suppl 4*, S71–S80.

Souza, J., & Raskin, S. (2013). Clinical and epidemiological study of orofacial clefts. Jornal de pediatria, 89(2), 137–144. https://doi.org/10.1016/j.jped.2013.03.010.

Spraycar M, editor. 1995. Stedman's medical dictionary. 26th ed. Baltimore: Williams & Wilkins.

Stelck, E. H., Boliek, C. A., Hagler, P. H., & Rieger, J. M. (2011). Current practices for evaluation of resonance disorders in North America. Seminars in speech and language, 32(1), 58–68. https://doi.org/10.1055/s-0031-1271975.

Tolarová, M. M., & Cervenka, J. (1998). Classification and birth prevalence of orofacial clefts. American journal of medical genetics, 75(2), 126–137.

Westreich, M., & Segal, S. (2000). Cleft lip in the Talmud. Annals of plastic surgery, 45(3), 229–239. https://doi.org/10.1097/00000637-200045030-00001

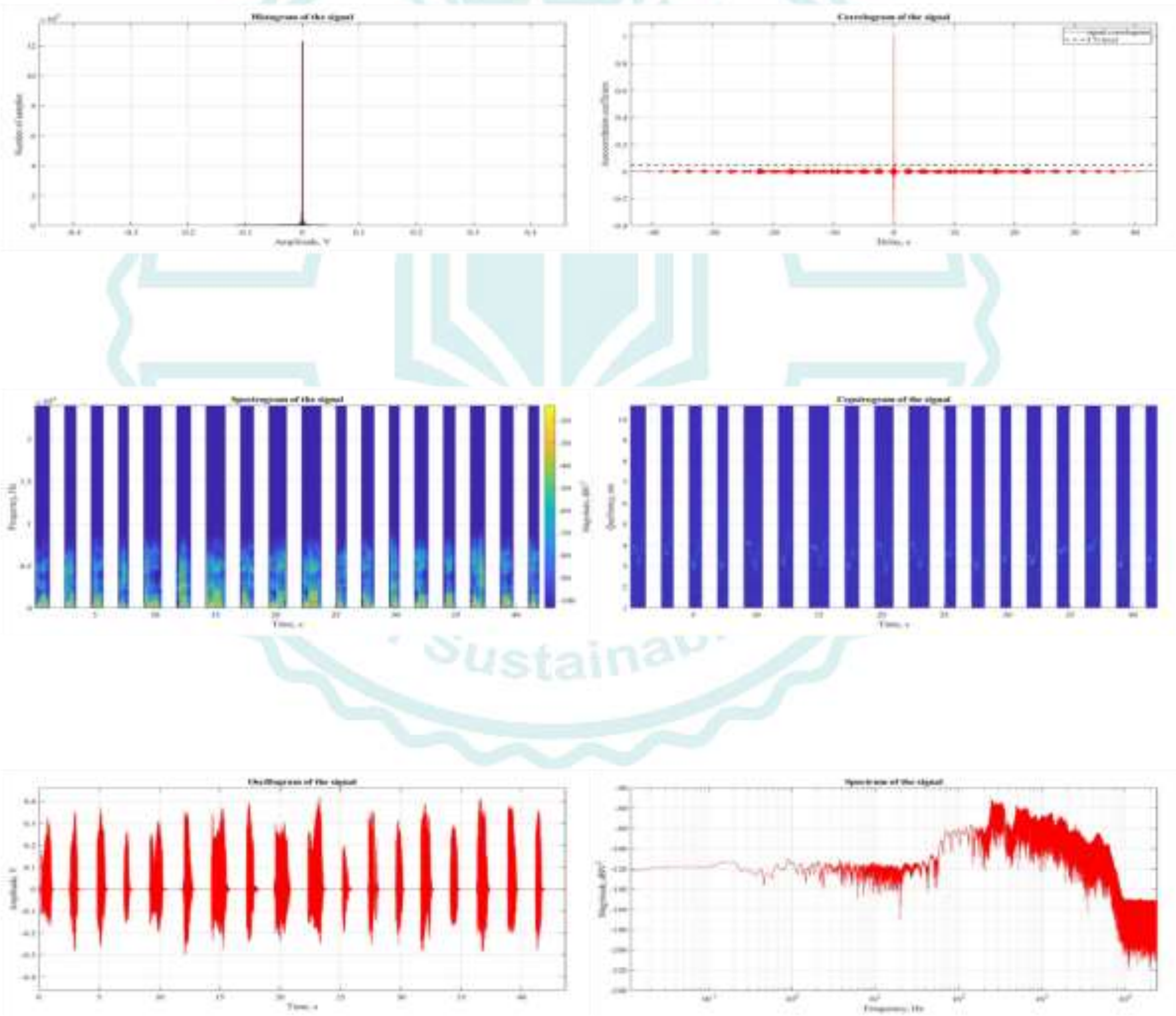
Witt, P. D., Wahlen, J. C., Marsh, J. L., Grames, L. M., & Pilgram, T. K. (1998). The effect of surgeon experience on velopharyngeal functional outcome following palatoplasty: is there a learning curve?. *Plastic and reconstructive surgery*, *102*(5), 1375–1384. https://doi.org/10.1097/00006534-199810000-00009.

Woo, A. S. (2012). Velopharyngeal dysfunction. In *Seminars in plastic surgery* (Vol. 26, No. 04, pp. 170-177). Thieme Medical Publishers.

Zhao, S., Xu, Y., Yin, H., Zheng, Q., Wang, Y., Zhong, T., Li, Y., & Shi, B. (2012). Incidence of postoperative velopharyngeal insufficiency in late palate repair. *The Journal of craniofacial surgery*, *23*(6), 1602–1606. https://doi.org/10.1097/SCS.0b013e3182564910.

Appendix

1. Sample of Acoustic Images



2. Sample of acoustic reading

Pre-Surgery	
The crest factor dB	16.6112
The autocorrelation (s.)	0.086229
MAX VALUE	0.41898
MIN VALUE	0.2998
MEAN VALUE	3.4571
RMS	0.061891
Dynamic Range(DR)	82.7528
Single duration	43.68