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Contact Pattern of Alveolar Consonants in the Malay Consonants of Paralysis Subject using Electropalatography

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Abstract: Place of articulation plays an important part to produce different sounds. Besides the place of articulation, tongue is also an active articulator during a continuous speech. During the speech, the tongue moves around creating different sounds when it is placed at different place of articulation. The movement of tongue is controlled by muscles. The lack of muscle movement will produce inactive tongue movement. Paralysis is an example of the muscle weakness in a person resulting in difficulties to move. Paralysis may occur due to several factors including stroke and spinal cord injury (SCI). One of the indirect effects of paralysis is slurred speech and difficulty in speaking. This study aims to determine the contact pattern of five paralysed subjects during speech production of alveolar consonants in the Malay Language. The subjects had paralysis due to different aetiologies and with different medical history backgrounds. All participants were required to produce five single consonants; /d/, /t/, /l/, /n/ and /s/. The data recording was done in a studio laboratory with a soundproof system. The device used for detecting the tongue and hard palate contact in this study was electropalatography (EPG). Subjects were required to wear the artificial palate consists of 62 sensors to detect the tongue and hard palate contact. The speech contact was analysed using Articulate Assistant 1.18™. The results were then compared with the average contact pattern of Malay speaker which had been obtained in the previous study. In conclusion, the subjects who had frequent treatments produced better articulation and the subjects with positive attitudes produced better articulation during the treatment process.

Keywords: Alveolar Consonant, Malay Language, Electropalatography, Paralysis

1. Introduction

Articulation is a combination between respiratory organs (lungs, throat, vellum, mouth, and nose) and speech organs or articulators (lips, tongue, soft palate, hard palate and teeth) in order to produce speech sound [1]. During speech, human produce many types of sound due to the characteristic of each sound. The place and manner of articulation, including the articulator are important elements to generate different speech sounds. In Malay language, there are six types of manner of articulation, and six types of place of articulation [2]. The manners of articulation are plosive, nasal, affricate, fricative, approximant and lateral approximant while the places of articulation are, alveolar, postalveolar, velar and glottal [3]. Speech is one of the essential elements in communication. Failure of speech may cause communication breakdown. The failure of speech is caused by a number of problems, commonly health problem. Wendy et al. (2018) in their study stated that, there are differences in hearing and speech difficulties as well as facial appearances for the people

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with cleft palate [6]. Besides from the cleft palate patients, paralysis subjects also face difficulties in speech. Paralysed subjects may suffer difficulties with their tongue and other muscles movements due to the damage to the peripheral nervous system. This situation results in the weakness and lack of coordination in the muscles movements as muscles are important in the body movement [7].

There are three types of muscle namely; smooth, skeletal and cardiac. The skeletal muscles can be controlled consciously and are attached to skeletal system, whereas, the smooth and cardiac muscles, such as heart and lungs muscles cannot be controlled [8]. During the body movement, the brain transmits the signal to the muscle. The failure of signal transmission will negatively affect the muscle movement according to the instructions from the brain [9]. This situation is commonly experienced by paralysed patients.

Other than body movement, paralysis also affects the articulation process. Consequently, it will indirectly prevent control over several human organs such as lips, throat and tongue. However, the lack of speech can be improved by speech therapy treatment. Paralysis can be classified into four categories which are monoplegia, hemiplegia, paraplegia and quadriplegia [2]. Paralysis among Malaysian is commonly due to stroke [10].

In Malaysia, the treatment for patients with paralysis are mainly focused on body movement treatment rather than speech treatment. There are many equipments used to help these patients [11]. However, there is no quantitative assessment used by therapist during speech rehabilitation. Speech therapists in Malaysia use perceptual analysis, which allows them to record and replay the speech sound. This technique is, however, difficult to be applied in the production of a continuous speech. Moreover, perceptual analysis is highly depending on the therapist skills and for the recorded speech, the quality of the audio is a crucial issue to be considered.

In this study, electropalatography (EPG) is used to determine the contact pattern in the production of alveolar consonants. EPG is an instrument used to monitor contact pattern between tongue and hard palate during a continuous speech with a real-time visual [12]. EPG consists of artificial sensor, signal reader and articulate software (Fig. 1). In this study, EPG3 is used to detect the contact pattern. The artificial sensor used to detect the tongue and hard palate contact is known as the Reading palate. The Reading palate consists of 62 electrodes embedded on the acrylic resin.

In order to obtain an accurate data, the fabrication of the Reading palate must be as thin as possible. The data from the Reading palate would be transmitted to a computer through a signal reader; multiplexer, and the speech signal was displayed on a computer through Articulate Assistant 1.18™ [2]

In this study, EPG is used to determine the contact pattern in the production of consonants /d/, /t/, /s/, /n/ and /l/ for paralysed subject. A total of five paralysed subjects have been selected to produce five alveolar consonants and compare their contact pattern with the average contact pattern produced by the normal subjects. The paralysed subjects were asked to wear the Reading palate during the speech recording.

Fig. 1 - EPG system and the Reading palate with 62 silver electrodes

2. Place of Articulation

In the Malay language, alveolar region consists of five consonants which are /d/, /t/, /s/, /n/ and /l/, in which /d/ and /t/ are categorised as plosive consonants, /s/ is categorised as fricative consonant, /n/ is categorised as nasal consonant and /l/ is categorised as lateral approximant consonant [1]. Table 1 shows the places and the manners of articulation in the Malay consonants. The production of alveolar consonants is generated when the tongue touches the anterior part of the hard palate. During the production of alveolar consonants, the main organs involved are tongue and hard palate. Hard palate and tongue play an important role in differentiating a particular sound. During the speech, the tongue moves around and placed at different parts of articulation in the hard palate to produce a sound [4]. However, the speech sound is different between the manners of articulation eventhough the consonant is categorised as alveolar consonant.

In the production of plosive consonants, the tongue closes the alveolar zone of hard palate. Meanwhile, the air flows were accumulated in the oral cavity and would be released immediately to produce a plosive sound. Additionally, fricative consonants are generated when the tip of the tongue touches the alveolar of hard palate while the end of the tongue rises up causing a narrow space. The air flows through the narrow space to produce the fricative sound. In the production of

nasal consonant, the tip of the tongue approaches the alveolar of the hard palate while the back of the tongue constricts the air flows in the oral cavity. The air flows enter the nose and produces nasalance sound. Meanwhile, lateral approximant is generated when the tip of the tongue approaches the alveolar of the hard palate and the air flows through the oral cavity [5].

Table 1 - The Malay consonants according to manners and places of articulation

Manner of Articulation	Voicing	Place of Articulation				
		Bilabial	Alveolar	Postalveolar	Velar	Glottal
Plosive	Voiced	b	d		g	
	Voiceless	p	t		k	
Fricative	Voiced		s			h
	Voiceless					
Affricate	Voiced			ʧ		
	Voiceless			ʤ		
Nasal	Voiced	m	n		ŋ	
Lateral approximant	Voiced		l			
Approximant	Voiced			r		

3. Methods

This study has been approved by the Human Research Ethics Committee (HREC) of Universiti Sains Malaysia (USM). All subjects involved were required to sign the informed consent before conducting the procedure Information of the study and informed consent procedures were briefed by the clinicians involved in this study.

3.1.Subjects

Five paralysed subjects; Patient1 (P1), Patient 2 (P2), Patient 3 (P3), Patient 4 (P4) and Patient 5 (P5) with different medical backgrounds were selected for this study with age ranging from 47 to 56 years old. P1 is a housewife, P2 and P3 had retired from work, meanwhile, P4 and P5 were self-employed. All of the subjects were classified as hemiplegia. Additionally, P1, P2 and P5 use full dentures. Table 2 shows the details classification of the studied subject.

3.2.Procedure

The first procedure involved the impression taken by dental officer. The subject's upper arch was fabricated using Plaster of Paris (POP); referred as a study model. Then, a mixture of acrylic powder and monomer liquid was placed on the study model. Next, the silver electrodes were soldered to the copper wire before being embedded to the acrylic palate. Finally, the copper wires were soldered to the connector board (Fig. 2) [2].

During the data recording, all subjects were asked to wear the Reading palate. The Reading palate was connected to the multiplexer to transfer the contact signals from the tongue and hard palate to a computer. The data were then displayed on the computer using Articulated Assistant ™ 1.18 software. Before recording, subjects were asked to wear training palate for at least four hours. The training palate was used to accustom unfamiliar object in the subject's mouth, which is very important for producing accurate data during the speech recording [3].

Subjects were required to produce single consonants /d/, /t/, /s/, /n/ and /l/ in a studio laboratory equipped with soundproof system given that a quiet surrounding was needed during data recording. The contact patterns produced were transmitted and demonstrated in the computer upon reading the consonants /d/, /t/, /s/, /n/ and /l/. In this study, contact pattern displayed by the paralysed subjects will be compared with the average contact pattern of the normal Malay subjects. The average contact patterns were obtained from separate study which involves 30 normal speakers.

Table 2 - Classification of the subjects

Patient	Age (Year)	Gender	Years of Paralysis	Denture Usage	Paralysis category
P1	54	Female	1	Full denture (upper)	Right-Hemiplegia
P2	56	Male	2	Full denture (upper)	Right-Hemiplegia
P3	52	Male	3	No denture	Right-Hemiplegia
P4	47	Male	4 Month	No denture	Left-Hemiplegia
P5	52	Male	3	Full Denture (upper)	Left-Hemiplegia

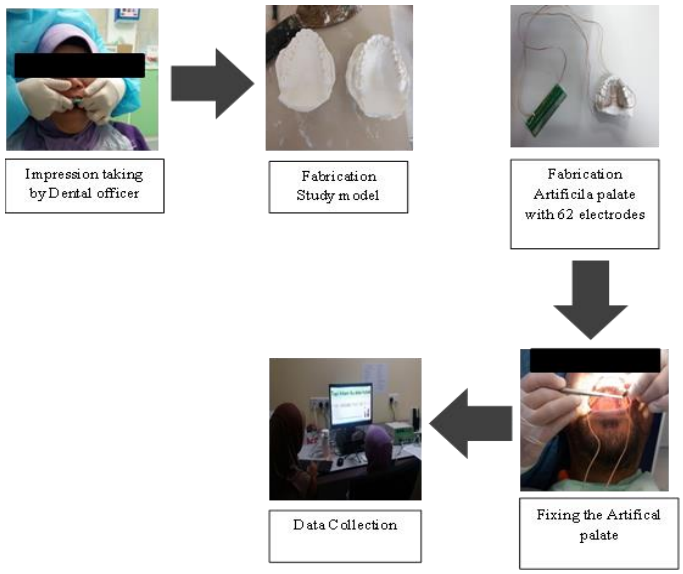


Fig. 2 -The fabrication process of the Reading palate

In this study, Reading palate was classified into four zones; alveolar, postalveolar, palatal and velar. The contact patterns displayed were discussed based on the zones. Alveolar zone is placed behind the central incisor to the end of the canine teeth. Postalveolar zone is located behind the end of canine to the end of first premolar teeth, meanwhile palatal zone is placed after the second premolar teeth to the end of first molar teeth. Velar zone is the back region placed at the second molar teeth. Fig. 3 shows the Reading palate with its palate zones.

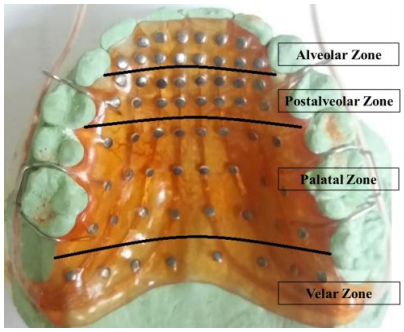


Fig. 3 -The Reading palate with its palate zone

4. Result

Table 3 shows the contact patterns in the production of alveolar consonants for five subjects. The data from the subjects were compared with the average contact produced by the normal subjects. In the production of consonant /d/, the average contact recorded for the normal subjects were 36 contacts. There were 14 contacts at the alveolar, 11 contacts at the postalveolar, seven contacts at the palatal and four contacts at the velar zone.

For consonant /t/, the average contact recorded were 36 contacts. A total of 14 contacts were located at the alveolar zone, nine contacts at the postalveolar, nine contacts at the palatal and four contacts at the velar zone. Meanwhile, in the production of consonant /l/, the average contact recorded a total of 28 contacts, in which 14 contacts were located at the alveolar, nine contacts at the postalveolar, four contacts at the palatal and one contact at the velar zones.

For consonant /n/, the total contact recorded were 29 contacts, in which 14 contacts situated at the alveolar, six contacts at the postalveolar, six contacts at the palatal and three contacts at the velar zones. Furthermore, there were 11 contacts at the alveolar, five contacts at the postalveolar, five contacts at the palatal and two contacts at the velar zones for consonant /s/.

Five paralysed subjects were identified as P1 until P5. P1 was identified as a female subject suffering from paralysis for one year. She did not receive any treatment or rehabilitation since the treatment centre is far from her house. In addition, P1 was categorised as a right-hemiplegia patient. In the production of consonants /d, /n/ and /s/, the contacts occurred at the lateral of the hard palate. However, there was no contact between the tongue and hard palate in the production of consonant /t/. At the alveolar zone, consonants /d/ and /n/ had two contacts, whereas there was no contact for consonants /l/, /t/ and /s/. At the postalveolar zone, there were four contacts for consonant /d/, six contacts for consonant /n/, two contacts for consonant /s/, one contact for consonant /l/ and no contact for consonant /t/. Meanwhile at the palatal zone, there were 11 contacts for consonant /d/, two contacts for consonant /l/, five contacts for consonant /n/ and four contacts for consonant /s/. At the velar zone, there were four contacts for consonant /d/, one contact for consonant /l/, three contacts for consonant /n/ and two contacts for consonant /s/. In the production of consonant /t/, P2 had no contact for all palate zones.

P2 was a male subject suffering from paralysis for two years. He attended treatment at a government hospital regularly. P2 had the most similar contact pattern with the average contact in the production of consonants /n/ and /s/. Meanwhile, there were contacts at posterior of the hard palate in the production of consonants /d/ and /l/ and scattered contacts between tongue and hard palate in the production of consonant /t/. At the alveolar zone, there were no contact for consonant /d/, 12 contacts for consonant /t/, three contacts for consonant /l/, 11 contacts for consonant /n/ and seven contacts for consonant /s/. At the postalveolar zone, there was no contact for consonant /d/, 13 contacts for consonant /t/, eight contacts for consonant /l/, 12 contacts for consonant /n/ and eleven contacts for consonant /s/. At the palatal zone there were five contacts for consonant /d/, 15 contacts for consonant /t/, 13 contacts for consonant /l/, 10 contacts for consonant /n/ and six contacts for consonant /s/. Meanwhile at the velar zone, there were three contacts for consonant /d/, six contacts for consonant /t/, five contacts for consonant /l/, no contact for consonant /n/ and two contacts for consonant /s/.

For P3, consonants /l/, /n/ and /s/ showed the most similar contact pattern between tongue and hard palate with the average contact. As for the production of consonants /d/ and /t/, it was observed that the contacts were focussed at the lateral side of hard palate. P3 was a male subject who suffered from right hemiplegia paralysis for more than three years. P3 had been regularly following up with the treatment until now. At the alveolar zone, there was no contact for consonant /d/, one contact for consonant /t/, seven contacts for consonant /l/, 12 contacts for consonant /n/ and five contacts for consonant /s/. At postalveolar zone, there was no contact for consonant /d/, four contacts for consonant /t/, two contacts for consonant /l/, two contacts for consonant /n/ and three contacts for consonant /s/. At the palatal zone, there were eight contacts for consonant /d/, nine contacts for consonant /t/, one contact for consonant /l/, two contacts for consonant /n/ and two contacts for consonant /s/. At the velar zone, there were five contacts for consonant /d/, three contacts for consonant /t/, one contact for consonant /l/ and /s/ and two contacts for consonant /n/.Interestingly, during the treatment, P3 drove his car on his own.

P4 was classified as a left-hemiplegia paralysis patient who had been attending the treatment regularly. According to the subject, he had been facing the speech problem four months prior to this study. He had the most similar contact for consonants /t/, /l/ and /n/. However, in the production of consonant /d/, the contacts were at the alveolar zone on the left side of hard palate. At the alveolar zone there were two contacts for consonant /d/, six contacts for consonant /t/, eight contacts for consonant /l/ and five contacts for consonant /n/. At the postalveolar zone, there were five contacts for consonant /d/, 10 contacts for consonant /t/, nine contacts for consonant /l/ and six contacts for consonant /n/. Besides consonant /d/ had eight contacts, consonant /t/ had nine contacts, while consonant /l/ and consonant /n/ had three and four contacts, respectively at the palatal zone. At velar zone, there were four contacts for consonant /d/ and consonant /t/ and two contacts for consonant /l/ and consonant /n/. Additionally, P4 had no contact for all zones in the production of consonant /s/.

P5 was a male subject who had left-hemiplegia since three years ago. He attended the check-ups for the past two years. He had physically recovered for almost 80%. P5 had almost similar contact pattern in the production of consonants /l/ and /n/. There were contacts at the lateral of hard palate in the production of consonants /d/, /t/ and /s/. P5 had no contact at the alveolar zone for consonant /d/, one contacts for consonant /t/ and /s/, 11 contacts for consonant /l/, and 13

contacts for consonant /n/. At the postalveolar zone, there was no contact for consonant /d/, one contact for consonants /t/ and /s/, four contacts for consonant /l/ and six contacts for consonant /n/. At the palatal zone, there were two contacts for consonants /d/ and /t/, no contact for consonant /l/ and /n/, and three contacts for consonant /s/. At velar zone, there were two contacts for consonants /d/ and /n/, three contacts for consonant /t/, one contact for consonant /s/ and no contact for consonant /l/.

Table 3 - The production of alveolar consonants comparing the average contact of normal subjects and paralysed subjects (P1 to P5)

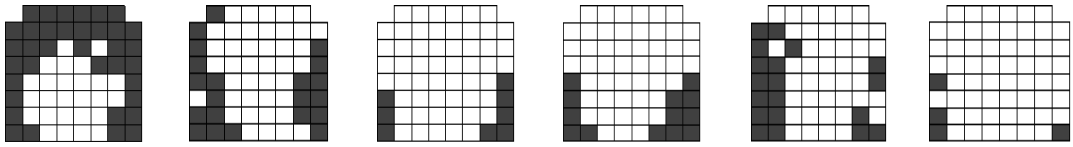
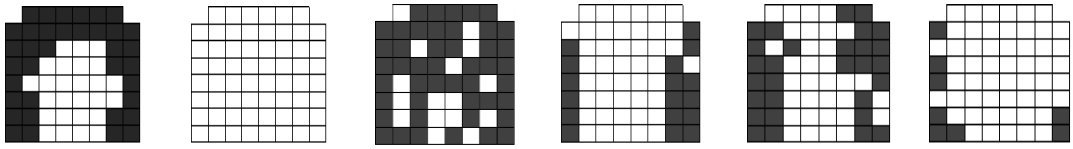
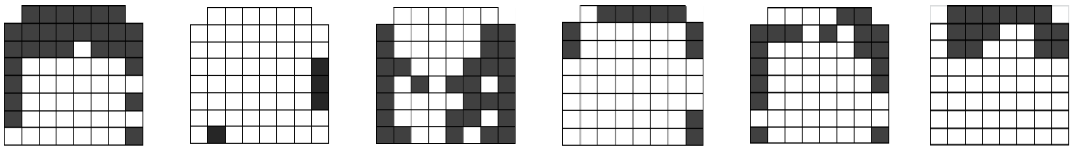
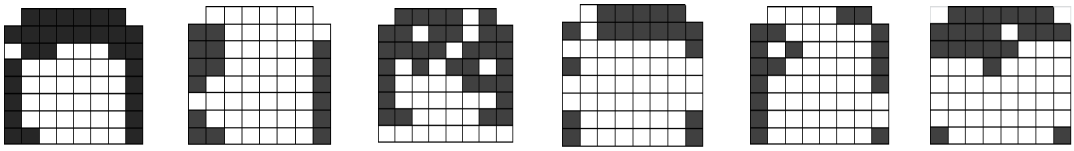
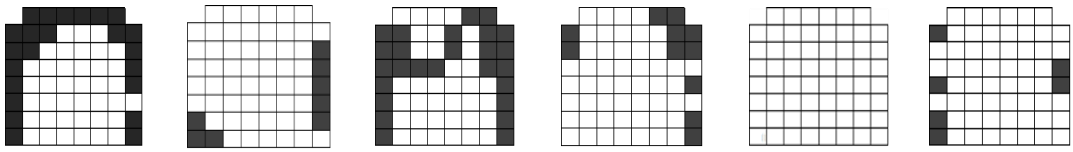
Consonant	Average Contact	P1	P2	P3	P4	P5
d						
t						
l						
n						
s						

Fig. 4 shows the percentage of contact in the production of alveolar consonants. In the production of alveolar consonants, the average contact showed the highest percentage at the alveolar zone, whereas the palatal had the lowest percentage except in the production of consonant /l/. For consonant /d/, all subjects had different findings in term of the palate zone compared to the average contact. The average contact had the highest percentage at the alveolar zone meanwhile all subjects had the highest percentage at the velar zone. Additionally, P2, P3 and P5 had no percentage of contact at the anterior of the hard palate. In the production of consonant /t/, P2 showed almost similar percentage with the average contact. The highest percentage was at the alveolar zone while the lowest percentage was at the palatal zone for both P2 and average contact.

In the production of consonant /l/, P3, P4 and P5 had higher percentage of contact at the alveolar zone similar with the average contact. However, P3 and P4 had the lowest percentage at the palatal zone and P5 had no contact at the palatal and velar zones. Meanwhile, P2 and P3 had the highest percentage at the velar zone.

For consonant /n/, P2, P3 and P5 had the highest percentage at the alveolar zone but the lowest percentage at the palatal zone except for P3 who had the lowest percentage at the velar zone. P4 had the highest percentage at the postalveolar zone and the lowest percentage at the palatal zone. Additionally, P1 showed a similar percentage of contact with the average contact at the postalveolar and velar zones.

P3 had similar percentage with the average normal subjects, which was the highest percentage of contact at the alveolar followed by the postalveolar, palatal and velar in the production of consonant /s/. P2 on the other hand, had the highest percentage at the postalveolar zone followed by alveolar zone. Meanwhile, P1 and P4 had the highest percentage at the posterior of the hard palate.

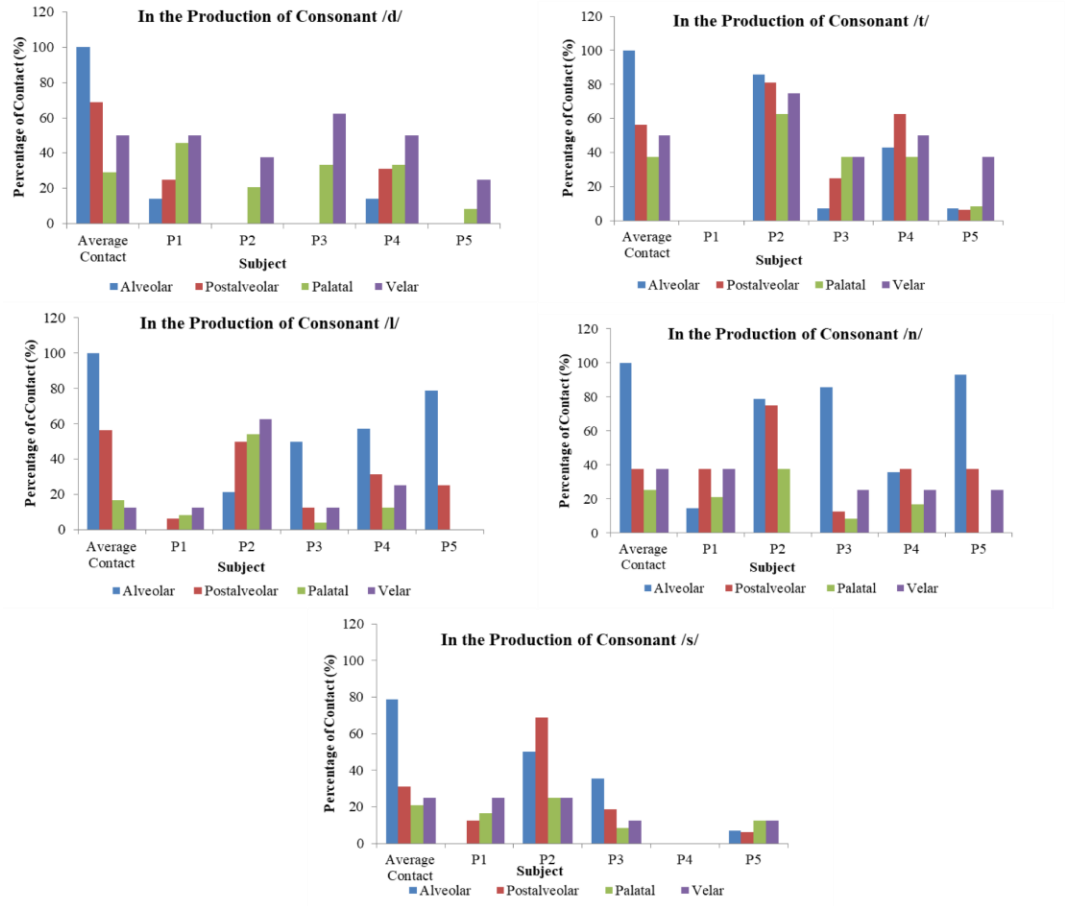


Fig. 4 - Comparison of contact percentage for alveolar consonant (/d/, /l/, /t/, /n/ and /s/) among average normal subjects and paralysed subjects.

5. Discussion

Consonants /d/ and /t/ can be classified as alveolar plosive consonants. During the production of alveolar plosive consonants, the tip of the tongue is close to the alveolar zone of the hard palate. Meanwhile the soft palate rises up and the air accumulates in the oral cavity. In the production of consonant /d/, the result showed that P1 and P4 had a contact at the lateral side of the alveolar zone compared to other subjects who had no contact at the alveolar zone.

In the production of consonant /t/, P3, P4 and P5 had contacts at the alveolar zone eventhough the contacts only happened at the lateral side of alveolar zone, whereas, P1 had no contact and P2 had scattered contacts at the hard palate. It can be concluded that the alveolar plosive consonants are difficult to be produced by paralysed subjects. This is due to the fact that many muscles are involved in the production of the alveolar plosive consonants.

Consonant /l/ was categorised as lateral approximant consonant. This sound is generated when the tip of the tongue approaches the hard palate and the soft palate moves towards the throat. P3, P4 and P5 had almost similar contact pattern with the average contact at the anterior-lateral of hard palate, whereas P1 and P2 had contact at the posterior-lateral of the hard palate.

As for consonant /n/, it is a nasal consonant which is generated when the anterior of the tongue approaches the anterior of the hard palate. During the production, the tongue blocks the air flows from lungs and it enters the oral cavity resulting in nasalance sound. All subjects showed almost similar contact pattern in the production of consonant /n/. It is because during the production, only a minimum number of muscles involved to move the articulator [13]. According to Jesus et al. (2012), the production of consonant /n/ in Portuguese language indicated that less articulatory force needed compared to the production of consonants /d/ and /t/. In addition, there was no difference in the production of consonant /n/ in Portuguese language compared with other languages such as English and Australian [4].

In the production of consonant /s/, P4 had no contact followed by P5 and P1. P2 and P3 had almost similar contact pattern eventhough P2 had more contacts at the middle of palatal zone. Consonant /s/ can be categorised as a fricative

consonant. It happens when the tip of the tongue closes the anterior part of hard palate and the posterior tongue of all fricative consonants create concave cross- sectional shapes to produce narrow space. The air flows through the narrow space producing a friction sound. P1, P4 and P5 showed lack of muscle strength to move the tongue and subsequently generated an imprecise pronunciation [14].

P3, P4 and P5 had almost similar contact pattern with the average contact for at least three consonants. These three subjects followed their treatments regularly. Besides, these three subjects had their own initiatives to improve the production of speech. However, all subjects only received treatment on upper and lower limp. All subjects had their own initiative to improve their pronunciation.

Furthermore, P4 was a unique subject who had a better production of alveolar consonants eventhough he had paralysis since four months prior to this study. According to his guardian, he is a positive minded person [15] and routinely doing exercises and practices to produce better articulation.

In addition, P2 had almost scattered contacts in the production of alveolar consonants. During data recording, P2 faced difficulties to swallow the saliva due to weak tongue movement [16]. Interestingly, P2 tried to produce the alveolar consonants correctly and the result indicated that the contact pattern generated for some consonants were almost identical to the average contact pattern of normal subjects.

In this study, some of the patients had different contact pattern between the paralysed sides during the articulation. However no statistical analysis was conducted to verify for the significance due to the small number of data. Graziella et al. (2017) conducted a study to identify the tongue pressure of the paralysed subjects. However, the results indicated that there were no significant differences in the tongue pressure between patients presented with right-hemiplegia or left-hemiplegia.

5.1.Procedure

The first procedure involved the impression taken by dental officer. The subject's upper arch was fabricated using Plaster of Paris (POP); referred as a study model. Then, a mixture of acrylic powder and monomer liquid was placed on the study model. Next, the silver electrodes were soldered to the copper wire before being embedded to the acrylic palate. Finally, the copper wires were soldered to the connector board (Fig. 2) [2].

During the data recording, all subjects were asked to wear the Reading palate. The Reading palate was connected to the multiplexer to transfer the contact signals from the tongue and hard palate to a computer. The data were then displayed on the computer using Articulated Assistant ™ 1.18 software. Before recording, subjects were asked to wear training palate for at least four hours. The training palate was used to accustom unfamiliar object in the subject's mouth, which is very important for producing accurate data during the speech recording [3].

Subjects were required to produce single consonants /d/, /t/, /s/, /n/ and /l/ in a studio laboratory equipped with soundproof system given that a quiet surrounding was needed during data recording. The contact patterns produced were transmitted and demonstrated in the computer upon reading the consonants /d/, /t/, /s/, /n/ and /l/. In this study, contact pattern displayed by the paralysed subjects will be compared with the average contact pattern of the normal Malay subjects. The average contact patterns were obtained from separate study which involves 30 normal speakers.

6. Conclusion

In this study, EPG is used to monitor the tongue and hard palate contact during speech production of a paralysed subject. Additionally, it is observed that EPG is a suitable instrument used to monitor and improve the speech production among speech disorder especially paralysed patients. The paralysed subjects may face difficulties in their speech due to the failure of muscle movements. The lack of strength in the muscles will affect the production of speech. All subjects have been classified as hemiplegia paralysis. P1, P2 and P3 had right hemiplegia, whereas P4 and P5 had left hemiplegia. The contact patterns for the production of alveolar consonants among the left and right hemiplegia was difficult to be distinguished. Additionally, individual comparison of the contact pattern is more meaningful as each contact pattern represent their own paralysis condition. However, it is undeniable that other factors such as frequency of treatment and type of paralysis also influence the findings of this study. In addition, the duration of paralysis and the frequency of the rehabilitation treatment may potentially give a significant impact towards better speech production.

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