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The kinematic analysis of speeching pattern on the anterior tooth relation

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전치부 교합분류에 따른 발음양상의 운동학적 분석

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구강악기능계의 유지와 재현은 치과 치료에서 매우 중요한 부분이다. 구강악기능계는 저작기능, 발음기능 그리고 연하기능과 관련되어 있는데, 저작시 하악 운동에 관한 연구는 기존에 많이 시행되어 왔지만, 발음기능시 하악 운동에 대한 연구는 거의 이루어지지 않았다. 실제 저작장애를 호소하는 환자 못지않게, 발음장애를 호소하는 환자들을 임상에서 많이 관찰할 수 있다. 그러므로 성공적인 치과치료를 위해서 발음 기능을 정확하게 평가하는 연구가 필요하다.

발음이란 후두를 통해서 나온 공기가 입술, 혀, 치아를 지나면서 만들어지는 것으로, 발음장애가 이러한 기관의 비정상적인 형태나 기능에서 기인할 수 있다. 이번 논문에서는 부정교합에 따른 발음양상을 운동학적으로 분석하여, 이들의 상관관계를 평가하였다. 컴퓨터화된 하악운동 추적조사 장치인 JT-3(BioPAK system®, Bioresearch Inc., USA)를 사용하여, 10명의 정상교합자와 30명의 전치부 부정교합자의 발음양상을 운동학적으로 분석하였다. 실험에 사용된 문장은 언어장애자와 정상인의 발음을 진단하는데 사용하는 '한국어 발음검사(이현복, 1991)'에서 발췌하였고, 단일음이 아닌 2개의 문장을 반복하여 읽게 하였다.

이상의 실험에서 다음과 같은 결과를 얻게 되었다.

1. 정상교합자와 전치부 부정교합자 사이에, 발음하는 동안 하악 운동의 형태나 위치에서 유의할만한 차이가 존재하였다.
2. 정상교합자와 전치부 부정교합자 사이에, 발음하는 동안 하악 운동 형태의 폭과 너비에서는 유의할만한 차이가 나타나지 않았다($p>0.05$).

이번 연구를 통해, 발음하는 동안 전치부 교합분류에 따른 하악의 운동 양상의 형태를 분석하여 그룹 간에 유의할만한 차이를 발견하였지만, 그 높이와 폭은 그룹 간에 유의차가 없는 것을 알게 되었다. 이러한 결과는, 정확한 발음을 만들어 내기 위한 하악의 보상적인 움직임에서 기인한 것으로 해석할 수 있다. 이번 연구를 토대로, 발음시 전치부 교합분류별 하악운동의 형태를 예측할 수 있었고, 이는 성공적인 치과치료와 진단에 유용할 것으로 사료된다.

Ⅰ. *INTRODUCTION*

Both rehabilitation and maintenance of the stomatognathic functional system are very essential in dental treatment. Therefore, the awareness and investigation of the functional movements of the mandible have been the continuous goals of the dental profession. The stomatognathic functional system includes mastication, speech, and deglutition. The mandibular movement during mastication has been extensively studied,[1-6] while the mandibular movement during speech remains rarely. However, patients who complain of speech disturbances are observed as well as those who have chewing disturbances. Therefore, the study for assessing speech function is needed to support successful dental treatment.

Speech is composed of a series of sounds broadly divided into consonants and vowels. Individual sounds, or phonemes, are produced by the passage of air through the larynx and the mouth over the tongue and out past the teeth and lips. Consonants are formed with the tongue directing the air flow through a narrow space between the teeth which are close together. Vowels are produced with the teeth more widely separated; the sound is modulated by the lips and tongue, with little influence from the teeth themselves. To be brief, Speech is accomplished by integrated function of organs in the stomatognathic system and is thought to be affected by the abnormalities of these organs. Therefore, the characteristic mandibular movement during speech may be theorized as being caused by malocclusion.[7]

Mandibular movement during speech has long been used as a guide for vertical dimension of occlusion and anterior guidance.[8-10] The influence of speech and phonetics on the construction of dentures has long been recognized.[12),14,15] However, obtaining accurate measurements of such movement has been difficult and detailed studies of the range of mandibular movement during speech are few.[17-19] Such work has generally been limited either by the equipment used, the small data pool, or the brevity of the text spoken.

Techniques for monitoring mandibular movements during speech include direct observation,[11-13] radiography[20] and long-duration photography.[21,22] These are suffered from some practical limitation such as lack of precision or a high level of radiation. Then, electro-mechanical[23] or opto-electronic devices[24] have also been used to measure the mandibular movement during function. They provide the desirable accuracy of measurement, but require the passage of some elements of the measuring system between the lips. Finally, the sirognathograph[25] and the kinesiograph[26] use a magnet in the mouth as a transponding element and have extra-oral transducers; these do not then interfere with lip sealing and have been successfully used to examine the speeching pattern.[18,19]

The words or phonemes examinated with these techniques have mostly been those where the teeth are close together, or are related to some other physiological manoeuvre, such as the rest position of the mandible. The movement of the jaw has been examined during the 's' sound[11),19),22] and the 'm' sound.[23),27] More extensive sequences of words and sentences have been used only rarely.[17),19),28] Only Gibbs and Messerman[17] have described a single speech pattern, but they did not disclose the composition of the text used. In brief, investigation of mandibular movement during speech has generally been limited to measurements of the static position of a determined sound, almost always a sibilant, as a guide for vertical dimension of occlusion and anterior guidance.[11),29),30] However, static position of a determined sound is not common during conversation. Therefore, analysis of mandibular movement during speech which is similar to that used in daily conversation is needed.

In this study, we have sought to examine the kinematic analysis of the speeching patterns between the normal occlusion group and the anterior tooth malocclusal groups, by the JT-3 (the BioPAK® system, Bioresearch Inc., USA) for tracking their jaw movements during reading. A long passage of text was read to study the whole range of movements and we examined the difference depending on the classification of malocclusion. The purpose of this study was to investigate the effect of anterior tooth relation on the mandibular movement during speeching in Korean and to analyze the kinematic differences among the groups.

Ⅱ. *MATERIAL AND METHODS*

A. Subjects

40 undergraduate dental students(23 men and 17 women) at Chosun University took part in our investigation. Their ages were ranged from 23 to 33 years with a mean of 25 years 1 months. The study included 10 normal control subjects(age range 23 to 33 years; a mean of 25.0 years) and 30 subjects having the anterior tooth malocclusion (age range 21-31 years; a mean of 25.1 years). Normal subjects had no malocclusion and had natural dentition with 2 to 3mm horizontal and vertical overlaps of the anterior teeth. Subjects who have malocclusion at only anterior teeth was included for this study. Because, speech disturbance results from malocclusion of mainly anterior teeth, and previous studies reported that malocclusion of posterior teeth such as posterior reverse occlusion or lingually malposed mandibular occlusion does not show significant difference in speech pattern[35]. The anterior tooth malocclusal groups consisted of 10 subjects with deep vertical overlap(greater than 6mm) occlusion, 10 subjects with edge-to-edge occlusion, and 10 subjects with anterior open occlusion.

Each subject had the full complement of natural teeth, except unerupted third molars or any which had been extracted because of overcrowding. The subjects had no known neuromuscular or temporomandibular joint problems.

Table 1. The classification of subject group.

Group	Occlusion	Subjects
I	Normal occlusion (control subjects)	10
II	Deep vertical overlap occlusion (>6mm)	10
III	Edge to edge occlusion	10
IV	Anterior open occlusion	10

B. Electrognathograph

Electrognathograph was coined newly by Arthur Lewin.[36),37)] He was the original developer of the Siemens Sirognathograph. It is a generic term, not trademarked by anyone. EGN is commonly used as an acronym.

The most important feature of the Magnetic Jaw trackers(EGNs) is that they do not use clutches and do not interfere with functional activities such as chewing, swallowing and speeching. The second feature that is nearly as important for clinical applications is the ease of set up. The speed of set up is due in part to the fact that today's EGN devices remain 3 dimensional and record from an incisor-point that is in the area of greater movement. Also, when analyzing functional movements such a chewing, pattern recognition can be very effective substitute for actual full description of the movements.

Analyzing mandibular movements by magnetic methods involves some compromises and errors. Certain movements repositioning the magnet to the mandibular incisors and reattaching the magnet sensing devices to the head by means of special frames, cannot be precisely duplicated in repeated measurements. Additionally, inherent non-linearities result in distortion of the spatial location of the intra-oral magnet.

In this study, JT-3 device in the BioPAK® system(Bioresearch Inc., USA) was used. The BioPAK® system is highly accurate in measuring both speech pattern and masticatory movements. And in our study, we operated the experiments for three times and checked the accurate set-up of the device and instructed the subjects to border movement, in order to reduce the possibility of error which could be arised from the device itself and lead the subjects to make reproducible movements.

C. Measurement

First, we inputted the data about name, birth and sex of the subjects into the computer. The magnet was attached to the labial surface of mandibular incisors of the subjects in order to bring the midline of the magnet with the labial frenum and locate the groove of the magnet to the left side to the subjects. If the subject tends to have deep bite so that it is impossible to attach the magnet, it can be considered to attach to the labial gingival surface or lingual tooth surface. And then, the JT-3 device was set to the subjects.(Fig. 1) Once, the horizontal and vertical standard point were set, and we controlled them to fit with the subjects' heads. It should be controlled that the bar of the front side is paralleled to the interauditory axis, the bar of the lateral side to the Frankfort Horizontal plane, and the lateral line to the floor. The accessory bar for approaching to the magnet was fixed temporally and controlling minutely was operated in order to set the exact midline. During the measurement of the orbit of mandibular movement, the JT device was supported by the nose prop and the subjects holded the bilateral side of the JT-3 for convenience.

After the complete setting of the JT device, we instructed the subjects to enforce protrusive and lateral movements and repeat the standard text at a normal rate and with a loudness required for conversation. Two sentences were chosen from "Lee-Kim test of Korean Articulation(Hyun-bok Lee, 1991)[38]" for this experiment. This test is to diagnose normal and impediment in speech, and it is consisted of 11 sentences. In the sentences that we used for our experiment, various pronunciations that could be articulated in Korean was mixed. Especially, the sentence which was consisted of sibilant consonants and various vowels was chosen for the second sentence.

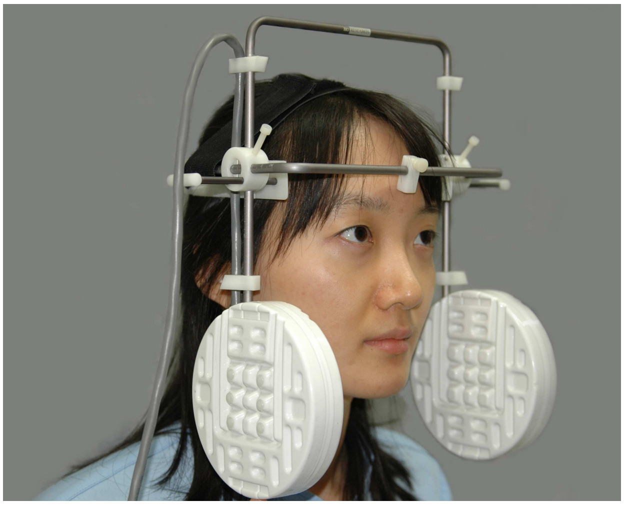

Fig. 1. JT-3 device was placed on the subjects (BioPAK system®, Bioresearch Inc., USA)

In the mode of ROM(Range of Motion) for twenty seconds, protrusive and lateral tooth guidance movements were recorded. All these border movements were limited to edge-to-edge or cusp-to-cusp points. And then, the subjects were instructed to read the first sentence "마음씨 좋은 누나는 영희에게 생일 선물로 파란 리본을 골랐다. (Ma - eum - ssi Jo - eun Noo - na - neun Young - hee - ae - ge Saeng - il - sun -mool -lo Pa - ran Ribbon - eul Gol - latta)" twice for twenty seconds, after that, the second sentence "쌀쌀한 어느날 사냥꾼이 쏜 화살에 불행이도 사슴이 맞았다. (Ssal - ssal - han Uh - neu - nal Sa - nyang - koon - i Sson Hwa - sal - ae Bool - haeng - hi - do Sa - seun - i Ma - zatta)" twice and they were recorded. The maximum anterior point (A point), maximum posterior point(P point), maximum superior point(S point), maximum inferior point(I point), antero-posterior range(A-P range), supero-inferior range(S-I height), horizontal width(Lateral width) of speech patterns which was recorded during speech were calculated(Fig. 2). X coordinates was measured so that A and P point were used for comparative analysis of antero-posterior mean among the groups. And Y coordinates was measured so that S and I point were used for comparative analysis of vertical mean among the groups. A-P range, S-I range, and lateral range were measured and the groups were comparatively analyzed.

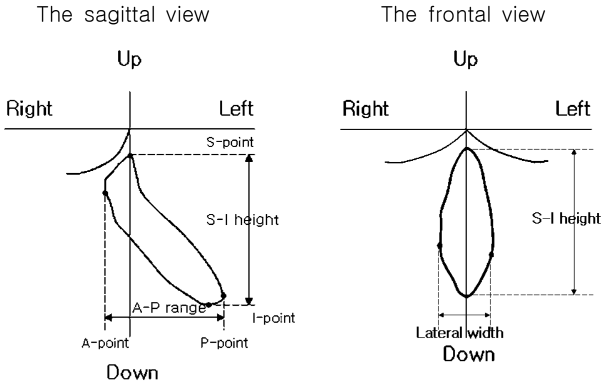

Fig. 2. Diagram to show the speech pattern and the measurements.

D. Statistical analysis

The statistical evaluation(One-way ANOVA analysis with Turkey test; level of significance, * : 0.01<P<0.05, ** : P<0.01) was performed to compare the coordinates of the four points(A point, P point, S point, I point) of the envelope, as well as the width and height of the envelop(A-P range, S-I range and lateral width), in each group of subjects having the anterior tooth malocclusion and in the normal control group by SPSS version 12.0. Because the number of each group of subjects is same, we use Turkey test as post-hoc analysis.

Ⅲ. *RESULTS*

A. The shape of the speech pattern

The cumulated jaw movements during speech described a pattern of movement that was characteristic and repeatable for any individual. A representative speech pattern for each group is shown in Fig. 3-6.

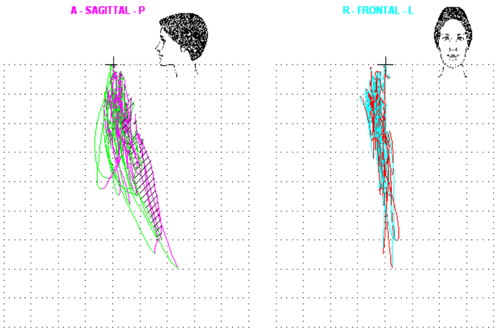

Fig. 3. Group I speech pattern

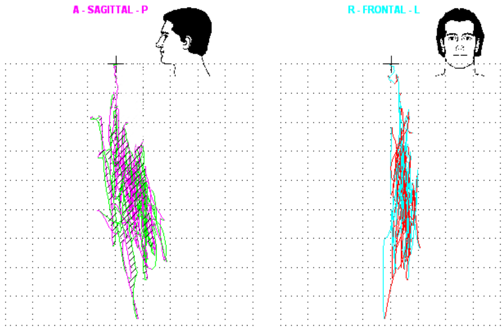

Fig. 4. Group II speech pattern

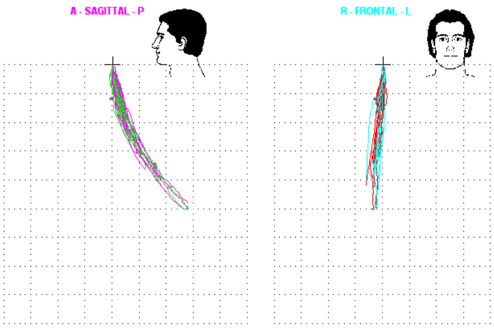

Fig. 5. Group III speech pattern

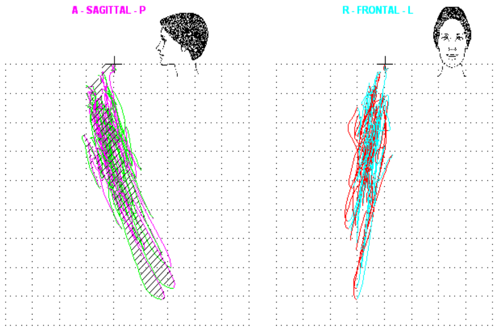

Fig. 6. Group IV speech pattern

1. Group I speech pattern shape(Fig. 3).

From a frontal view, the mandibular movements occupied a long narrow area, 2.5 mm (mean value) wide, on both side of the midline. The outline extended downwards for 11.7 mm (mean value) below the intercuspal position. The outline was wider superiorly and tapered inferiorly.

From a lateral view, the cumulated movements formed a parallelogram 3-4mm wide directed inferiorly and posteriorly across a vertical line passing through the intercuspal position.

2. Group II speech pattern shape(Fig. 4).

From the frontal view, the pattern of movement was similar to that of Group I subjects, but the general pattern was located more inferior than that of Group I. It was shown that the pattern's most superior point of Group II was located more inferior than that of the other groups and there is significant difference ($p<0.01$)(Fig. 9.). And it was shown that the pattern's most inferior point of Group II was located more inferior than that of the group III and there is significant difference($p<0.01$)(Fig. 10.). The pattern of movement was then directed downwards and slightly backwards, almost entirely posterior to the intercuspal position. There was little forward movement of the mandible through the intercuspal position.

3. Group III speech pattern shape(Fig. 5).

The position of the speech pattern was more intimately related to the intercuspal position than in the other three groups. The most anterior point tends to be closed to intercuspal position, compared with the group II($0.01<P<0.05$) and the group IV($P<0.01$) and there is significant difference(Fig. 7). Furthermore, the most superior group is also closed significanatly to intercuspal position compared with the group II($P<0.01$)(Fig. 9). The pattern in the frontal and sagittal view was narrow.

4. Group IV speech pattern shape(Fig. 6).

The shape of the speech pattern was similar to that of Group I relationship, but the width in the frontal view appeared greater(Fig. 6). From a lateral view the whole pattern was positioned further anteriorly and for some subjects the whole speech pattern was entirely anterior to the intercuspal position. In comparison with Group I, III, the most anterior point is located more anterior with significant difference(P<0.01)(Fig.7).

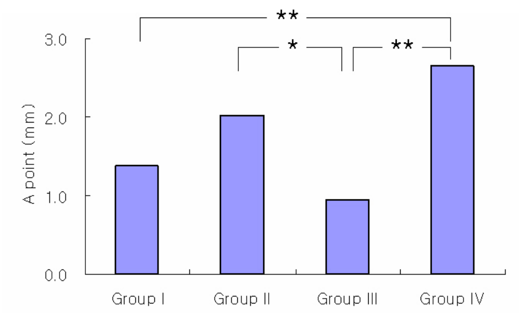

Fig. 7. Maximum anterior point comparison between groups.

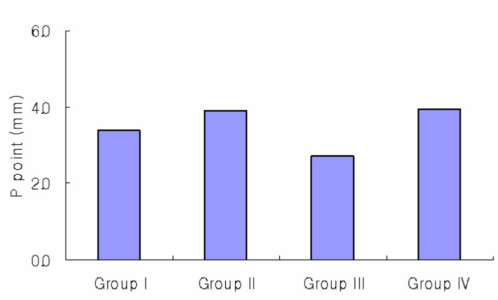

Fig. 8. Maximum posterior point comparison between groups.

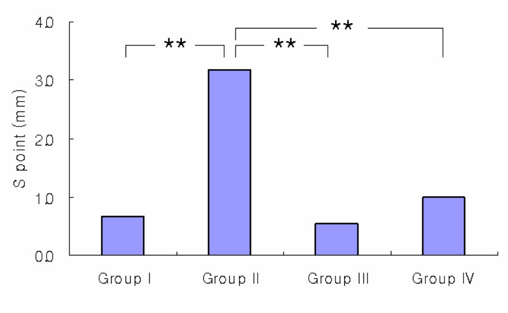

Fig. 9. Maximum superior point comparison between groups.

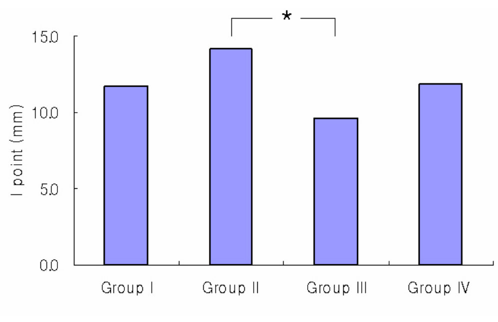

Fig. 10. Maximum inferior point comparison between groups.

(Fig. 7-10. * : 0.01<P<0.05, ** : P<0.01, Group I = normal occlusion; Group II = deep bite; Group III = edge to edge bite; Group IV = anterior open bite)

Table 2. The dimensions of the speech patterns(mm).

	Group I		Group II		Group III		Group IV		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Most anterior point(A point)	1.4	0.9	2.0	0.7	1.0	0.4	2.7	1.1	1.8	1.0
Most posterior point(P point)	3.4	1.7	3.9	1.3	2.7	1.6	4.0	2.8	3.5	1.9
Anterior-posterior range(A-P range)	5.1	1.5	5.9	1.5	3.7	1.5	6.6	2.2	5.3	2.0
Most superior point(S point)	0.7	0.5	3.2	0.8	0.6	0.3	1.0	0.3	1.3	1.2
Most inferior point(I point)	11.7	2.8	14.2	2.9	9.6	1.8	11.9	3.7	11.6	3.4
Vertical height (S-I height)	11.0	2.6	11.0	2.3	9.1	1.9	10.9	3.6	10.3	2.9
Lateral width	2.5	0.6	3.0	1.0	1.7	0.2	2.5	0.9	2.4	0.8

B. The dimensions of the speech pattern

In the A-P range, the S-I height and the lateral width, no significant difference was found between the normal occlusion group and the other malocclusal groups(Fig. 11, 12, 13), although there were significant differences among the malocclusal groups in the A-P range(Fig. 11).

The width of the speech pattern was narrow and ranged from 1.4 to 4.2 mm with a mean lateral movement of 2.4 mm. Group III subjects had the smallest lateral movements and this was significantly narrower than the group II ($P<0.01$)(Fig. 13).

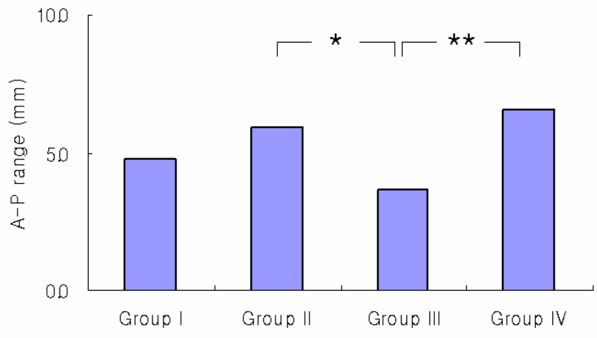

Fig. 11. A-P range measurements comparison between groups.

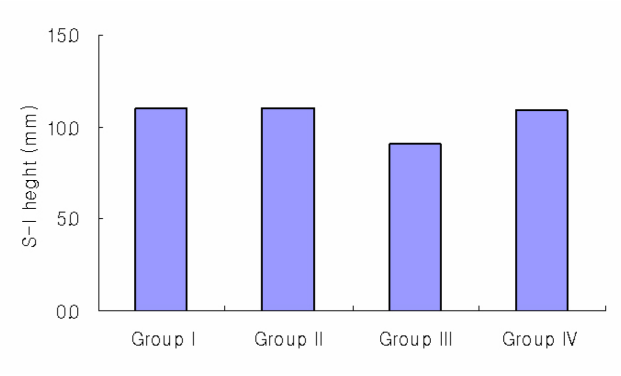

Fig. 12. S-I height measurements comparison between groups.

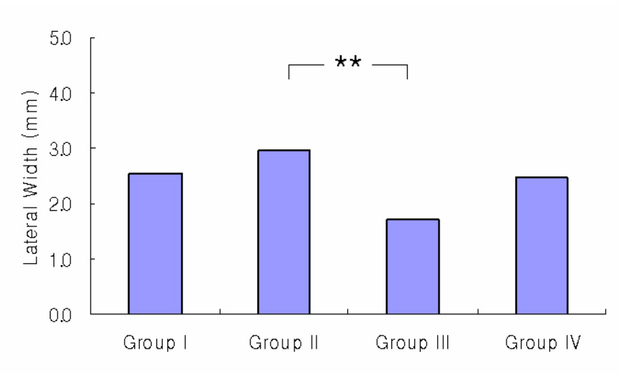

Fig. 13. Lateral width measurements comparison between groups.

(Fig. 11-13. * : 0.01<P<0.05, ** : P<0.01, Group I = normal occlusion; Group II = deep bite; Group III = edge to edge bite; Group IV = anterior open bite)

Ⅳ. *DISCUSSION*

The rest position appears to be the key to functional occlusion, as stated by Posselt[31] and Thompson.[32] Thompson stated that the vertical dimension of rest position should be used as the basis for treatment in orthodontics and in patients requiring extensive restorative procedures. Posselt's diagram of the envelope of motion shows that the angle of rest position to centric occlusion is different from the hinge axis. This could explain why changing the vertical dimension of occlusion by opening an articulator on its hinge axis usually fails to produce a clinical success, particularly if the terminal hinge position is located for the patient and transferred to the articulator.

This faulty change in the rest position or improper anterior restorations could result in leading to the muscular compromise and the compensatory mandibular movement was previously reported by Bendiktsson.[20] Speech disturbance resulting from improper anterior restoration or a change in the vertical dimension could be a common clinical observation.[33,34]

However, there have been no methods available for assessing speech function objectively. Techniques for the study of mandibular movement during speech have generally been of limited accuracy and have often been involved with subjective assessment. Some have examined merely the co-relationship between the physiological rest position of the mandible and certain speech sounds. and those have almost always been sibilants.[8),11),30] However, the static position of a determined sound is not a natural functional movement. Therefore, in this study, the method to read test sentence containing all speech sounds comprising korean language was constructed.

These methods yielding more precise answers to questions concerning mandibular movement during speech must be established to assist dental therapy. In this study, the relationships between malocclusion and mandibular movement during speech were analyzed.

Results suggested that the shape and location of the envelope of motion during speech are closely related to anterior tooth malocclusion. The ranges of movement of the mandible in the sagittal and frontal view(Fig.2) describe a pattern of speech which is characteristic for any individual. The dimensions of the speech patterns as previously published are similar to those in our investigation.[19,20),28)] Four distinct patterns of jaw movement during speech were observed(Fig. 3-6). These are attributable to the different incisor relations. The pattern is, in general, narrow with the lateral movements showing that there is little side-to-side movement during speech. In the sagittal view, the movements are directed backwards and downwards, as a result of the hinge-like movements of the mandible.

Based on this investigation, there are several possible explanations for significant difference in envelope coordinates between normal subjects and subjects having the anterior tooth malocclusion.

First, We could know that the mandibular movements avoid the interference near the intercuspal position during speech. This avoidance was observed significantly in the inferior deviation of the S-point in subjects with Group II(deep bite occlusion)($P<0.01$)(Fig.9).

Secondly, this investigation could show that the mandibular moves cooperatively to make an appropriate resonating cavity-closing the oral cavity to increase exhalation pressure. To make a resonating cavity, the lips, tongue, palate, and teeth coordinate to close the oral cavity.

For example, when there is lack of occlusal contact in the anterior teeth such as the Group IV(anterior open bite), the mandible moves anteriorly to close the oral cavity. In subjects having an anterior open bite(Group IV), these cooperative movements were observed as producing an anterior deviation of the A-point($P<0.01$). The movements of the Group IV appeared to be less well coordinated and were ill-defined, often with extraneous activity. It is as though these individuals are attempting to produce an edge-to-edge incisor relation during certain speech sounds. This would involve bodily anterior movement of the mandible, and could give rise to the unstable jaw position because of the large translation required. Otherwise, for subjects having edge-to-edge occlusion(Group III), there was significantly more posterior deviation of the a-point than group II and IV.($P<0.01$) This would involve a little bodily anterior movement of the mandible, and could give rise to the more stable jaw position because of the small translation required.

Thirdly, in this investigation, we could know that the mandibular on the anterior tooth malocclusion groups moves to keep the height and width of the envelope of motion similar to that of normal subjects.($P>0.05$) To make clear articulatory sounds, it is supposed that the envelope of motion changes its position for normal shape and volume of the resonating cavity. For example, when S-point deviates inferiorly, the I-point deviates inferiorly to maintain normal envelope height. These movements were observed in inferior deviation of the S-point and I-point in subjects with Group II($P<0.01$).

In the case of Group III, the reduced horizontal and vertical overlap of the incisor teeth was reflected in the speech pattern which was situated close to the intercuspal position. Their speech patterns as a whole were narrower in both the sagittal and frontal planes than those of the other groups. Additionally, their Anterior-posterior range of movement was the smallest.

And JT-3(BioPAK system®, Bioresearch Inc., USA) which was used for our experiments indicates several cautions for the accurate measurement. Key to quality of the electrognathography recording is that, how to attach the magnet at the accurate portion and not to lead intercuspal interference, how to check the accurate direction of the subjects and the jaw tracker placement and settlement, and whether the jaw tracker placement is installed therefore it should be checked by operating border movements before measurement. And the error that could be occurred during experiments can be reduced by observation the subjects and screen at the same time. Furthermore, we can expect the improved objectivity of the experiments and reduced errors through repeated measurements.

Ⅴ. *CONCLUSIONS*

Within the limitations of this study, the envelope of motion during speech was analyzed in 10 normal subjects and 30 subjects with anterior tooth malocclusion to investigate the effect of anterior tooth malocclusion on mandibular movement during speech.

Results were summarized as follows:

1. There were significant differences in the shape and location of the envelope of mandibular motion among the four groups.
2. The mandible on anterior tooth malocclusion moves to keep the height and width of the envelope of motion similar to that of normal subjects during speech. There are no significant differences in the height and width of the envelop of motion between normal subjects and anterior tooth malocclusion subject groups.

Based on the above results, we could expect the effect of anterior tooth malocclusion during speech and recognize the characteristic speech pattern envelope of mandibular motion for each anterior tooth malocclusion. These results indicate that the detailed analysis of the envelop motion during speech offers valuable information for diagnosis and initiation of dental treatment.

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